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Revealing the technical code.

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REVEALING THE TECHNICAL CODE

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Abstract

Contemporary technology is contentious subject matter within the social sciences. It is paradoxical, technology provides techniques and objects that serve humans in a positive way, but at the same time it can destroy the environment and dehumanize the labour process. A significant aspect of analyzing technology and society is accounting for the complex relationships that stand behind even the most mundane technologies. Andrew Feenberg seeks to account for this complexity with his critical theory of technology. The critical theory of technology identifies capital as a determining force in the design and function of technology. Revealing the influence of capital in apparent neutral technologies allows Feenberg to develop a dialectical concept of technological rationality that underscores the idea of a transformation of technological society to better reflect more humanistic and environmental needs.

Within the critical theory of technology, Feenberg critiques another approach to society and technology, actor-network theory. The purpose of this work is to examine and compare the claims of both the critical theory of technology and actor-network theory in order to examine how actor-network theory can complement the critical theory of technology. This will be achieved by identifying a commonality that can be found in both, the concept of society and technology combined as the sociotechnical. Within the sociotechnical, the concept of power as explained by both theories will be re-interpreted to illuminate how actor-network theory can complement the critical theory of technology.

Dedication

For my Dad, who has always provided optimism and support.

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Chapter One – Technology & Complexity

1.1 Introduction

Technology has always been a contentious matter in the social sciences. It can be viewed as a tool that can help liberate the human race from toil and suffering by enabling people to keep warm in the winter, refrigerate food, communicate over long distances, and prevent health problems. It can also be seen as a tool that furthers unequal power relations by reflecting the interests of the few at the expense of those whose lives are structured by the use of technology[1]:

> So far as decisions affecting our daily lives are concerned, political democracy is largely overshadowed by the enormous power wielded by the masters of technical systems: corporate and military leaders, and professional associations of groups such as physicians and engineers. They have far more to do with control over patterns of urban growth, the design of dwellings and transportation systems, the selection of innovations, our experience as employees, patients, and consumers, than all the governmental institutions of our society put together. (Feenberg 1995, p.3)

Technology effects everyone, yet those who are affected have little to no say in the direction of technological innovation. Manufacturing, data processing, and organizational technologies structure work relations hierarchically so that those who actually use the technology have no influence in the design of it. Technological innovation is responsible for pollution and environmental destruction, yet we as a population cannot transform the design of technology to lessen these harmful effects. Every citizen deserves the right to influence the direction of technologies that affect their lives and the environment in which they live. Minor regulatory changes do little to address the larger problem of unequal participation, a single minded approach to

[1] For the purpose of this work, technology will refer to the totality of materials used by humans that help to create and maintain our contemporary technological society.

efficiency, and a short sighted sense of the wide ranging effects of technological design and implementation. This undemocratic approach to technological design in our society is a significant problem that needs to be addressed.

The difficulty of addressing these issues is made clear when one considers the complexity that stands behind even the most ubiquitous technologies. Seemingly simple actions often conceal complex patterns of interactions that stand behind each of those actions. Nowhere is this more evident then in the relatively mundane exercise of operating an automobile. The initial manufacture of a car involves negotiations between labour unions and management, a Taylorist division of labour, and a capitalist system of production and consumption. Knowledge of how to operate a vehicle and the rules of the road are the immediate skills that must be embodied by the driver before he/she gets behind the wheel. Registering the vehicle and the driver, purchasing an insurance policy, and meeting the government's standard of acceptable emissions all have to be accomplished before one can legally drive an automobile. Once behind the wheel, the engine, steering wheel, brakes and transmission all have to perform in a specific way in order for the car to run. Using gasoline to power the vehicle is reliant upon another complex array of interactions between oil producing countries, trade agreements, the science of refining oil so that it can be used in an automobile, and the chain of retailers who sell the gasoline. Mechanics, dealerships and service shops are all involved at one point or another during the life of the car, extending the complexity. The people who manufacture and service cars receive an income from this work that pays for a variety of goods and services, provides financial security for their families, and through taxation contributes to social programs. The effects of actually driving the car are recognized in scientific data that links the internal combustion engine with harmful emissions that damage our environment. The infrastructure of roads, necessary for actually driving from one place to another, has destroyed countless acres of natural landscape.

Operating an apparently simple piece of technology like a car draws upon the driver's knowledge, institutional and governmental agencies, the laws of thermodynamics and other feats of engineering ingenuity, trade relationships, refineries, a system of exchange, Taylorism, the hole in the ozone layer, and the destruction of the natural environment. What may appear to be simply a technological artefact, the car, is in practise inseparable from driver's education courses, OPEC, the Federal Ministry of Transportation, trade unions, mass consumption, and scientific journal articles. How are we supposed to think about this complexity? By driving a car is someone implicated for crimes against the environment? What about crimes against third world workers who produce various bits and pieces of the car for unjust wages? The reality of living in a society that is heavily mediated by technology – meaning that the lives we lead are made possible only through the use of technology – is that we have to be aware of these complexities if we wish to change technology and society for the better.

It is not plausible or realistic to simply insist that society regress to a period where technological mediation is not as prevalent as it is today. Technology is not something that can be approached by a 'take it or leave it' attitude. The detrimental and positive aspects of technology exist simultaneously: Technological innovations provide long-distance communication, the opportunity to experience other cultures through global transportation systems and the material infrastructure of our societies - but these same technologies also pollute the environment and reproduce unequal power relationships.

Solving the problems that are inherent in our modern technological society requires an approach that recognizes the complexity of the interactions between society and technology without resorting to Luddite tactics or attempting to flee technology's influence by escaping 'back to nature'.

Andrew Feenberg recognizes both the complexity of our modern society and the undemocratic and unjust aspects of the technologies that surround us. Feenberg's systematic critique of contemporary technology, *Transforming Technology: A Critical Theory Revisited* (2002), provides a basis for theorizing the radical transformation of society and technology. The primary concept that Feenberg develops in his 'critical theory of technology' (henceforth CTT) is the 'technical code', a means of identifying specific social influences on technology. Feenberg uses this concept to trace the dominant social characteristics that define technology and to foreground the complex relationship between social factors and technical elements that are found in technology. Technologies, according to Feenberg, are "more than a sum of their parts…they meet a social criteria of purpose in the very selection of and arrangement of the elements from which they are built up" (Feenberg 2002, p.78).

Feenberg's critique is focused on contemporary capitalist society and the technologies that have been developed within it. Harmful environmental and social effects of technology are the result of the technical code of capitalism, a code that ensures that technology meets the dominant social requirements of capitalism. The capitalist technical code also enacts a distinct form of technological rationality that mirrors capitalist rationality in regards to efficiency and organization. Capitalist technological rationality also naturalizes a definition of the essence of technology as inherently neutral and determined only by technological, and not social, requirements. Identifying the technical code as the point at which technology is determined by the goals of capital is also to identify the point at which technology is 'ambivalent' and can potentially be transformed to meet the needs of a completely different society. Technology contains a hidden dimension that is blocked by capitalist technological rationality and by undertaking a 'rational critique of rationalism' Feenberg is able show that technology can exist in multiple forms reflecting diverse social requirements. Using the technical code, Feenberg is able to develop a concept of dialectical technological rationality that identifies the potential of contemporary technology to meet more holistic and egalitarian social and environmental requirements. Thus, the CTT provides a critique of our capitalist technological society, without falling into the pessimism or fatalism of other critical theories of technology, by providing a conceptual basis for positive technological transformation.

The CTT is dismissive of critical approaches to technology that reflect technological determinism. Technological determinism can be defined as the belief that "in some sense technical change causes social change, indeed that it is the most important cause of social change" (Mackenzie 1996, p.24). This type of critical approach to technology can be found, to varying degrees, in the work of Ellul (1964), Heilbroner (1967), and Winner (1986). Technological determinism subverts the CTT by negating the potential for radical technological change. If technology does determine society, this necessarily implies that the potential to transform technology to meet egalitarian and environmental goals and embody different design standards is doomed because technology, and not influences external to technology, determines modern society (Feenberg 2002, p.138).

Within *Transforming Technology,* and in other works (Feenberg 2000; Feenberg 2003), Feenberg makes a significant effort to critique another approach to technology and society, 'actor-network theory' (ANT hereafter). Feenberg contends that ANT is incompatible with the critical theory of technology because it contains "disturbing normative implications" that derive from its specific analytical strategy (Feenberg 2002, p.31). The goal of this work is to examine and compare the respective claims of Feenberg's theory and ANT. This opens up the possibility that ANT may provide complementary insights to the critical theory of technology. The rest of this chapter briefly introduces ANT and Feenberg's critique of it, and then conclude with an explanation of the approach that I will use to examine and compare these two approaches in the body of this study.

1.2 Actor-Network Theory

Actor-network theory was developed within the sociological study of scientific knowledge (Latour & Woolgar 1979; Callon, Law & Rip 1986; Latour 1987). The insights gained in these early studies were quickly applied to the study of technological innovations that varied between the Electric Car in France (Callon 1986a; Callon 1987), the development of the TSR2 military aircraft in Britain (Law 1988; Law 2002a; Law & Callon 1988; Law & Callon 1992), and the study of the mundane technical objects that make up our daily experience (Akrich 1992; Latour 1988a; Latour 1992).

ANT is a difficult body of work to summarize. Brown and Capdevila (1999) describe it as not a thing that circulates in an obvious and precise way (p. 29). Law

(1997) contends that ANT can only be performed, and not summarised or told as a single narrative. As a body of work, it changes as it is applied to different case studies. What ANT is then, is something that is constantly changing as it is applied in practise. ANT attempts to comprehend the complexity of modern technological society, and like the society that it attempts to describe, it cannot be reduced to a single, fixed point (Law 1999, p.10). In order to overcome the inherent difficulty of describing what ANT is, this work will focus primarily on the texts that originally introduced and explained the specific methodological and theoretical insights of ANT. Although a number of different concepts have been interjected, questioned, excluded, or qualified in relation to ANT, to address Feenberg's critique of ANT it is best to rely on the works that provide the original conception of ANT.

ANT examines technology and society by insisting that both are actually networks of human and nonhuman bits and pieces. The example of the car at the beginning of this chapter serves as an example of this approach. The car is not just a specific technology that can be examined in isolation; it contains a number of networks that mix humans, technologies, knowledge and politics. When the heterogeneous interactions that stand behind the car are stable, they disappear, replaced only by the action of driving a car. If these networks are not stable – the transmission fails, OPEC institutes an oil embargo or a prolonged strike affects the supply and demand of cars – the networks are exposed and the complexity is revealed.

A second postulate of the ANT approach is that an actor is the effect of the networks that stand behind it. The simple car is therefore both an actor and a network. Latour's study of Pasteur (1988b) illustrates this feature by showing that the relatively simple idea of 'Pasteur the great scientist' was actually nothing more than the effect of heterogeneous elements. This simple idea that is mythologized in history books is dependent on the laboratories, domesticated strains of bacteria, notebooks, statistics, journalists, the French electorate and the sheep that Pasteur experimented on. These complex networks combined to produce a single actor, Pasteur the great scientist. The argument therefore is that outside of this heterogeneous network, Pasteur the great scientist does not exist at all. Examining Pasteur in isolation from the materials that he used provides a false interpretation of how Pasteur was able to achieve both his results and his mythical status (at least in France). A single actor always represents, and is the effect of, a network (Callon & Law 1997, p.169). What is true of humans is also true of technology. Callon's study of the attempt to develop an electric car in France (the VEL) also reflects the idea that entities are effects of networked elements (Callon 1986a; Callon 1987). In order to develop and market an electric vehicle, the National French Utility (EDF) that initiated and co-ordinated this project, needed to network more than the technical elements of the VEL. A complex organization of laboratories, industrial companies, municipalities and consumers also had to be successfully networked to produce the VEL. Therefore, the technological artefact the VEL is in fact a network of humans and nonhumans, a heterogeneous network.

Strategically, ANT applies an approach to the study of technology that is called 'following the actors'[2] through every process of network creation. ANT always approaches the task of investigation empirically (Law 1992, p.387) in order to discover the complexity of social and technical influences that combine to create technology. The goal of this approach is to enter into the investigation of technology through the back-

[2] Actors in this sense are not just human, but also technological actors.

door of technology-in-the-making - not through the more grandiose door of ready-made-technology - in order to empirically understand the construction of both the technical and social network examined (Latour 1987, p.4). The premise of this approach is to open the 'black box' of technology. The term 'black box' is a term that refers to any object that contains a number of different elements organized as a complete whole. When many elements are made to act as one, this is a black box (Latour 1987, p.131). When technology is black boxed, it can also be considered stabilized. The complex interactions that make it up disappear and are replaced by the simple social and technological performance.

This insight leads to the next significant step in the ANT strategy: the assertion that what is commonly referred to as the social is not purely social; but is made up of heterogeneous materials. Of course, the social sciences have been aware of this for centuries,[3] but ANT takes this a step further by recognizing this in the process of investigating the complexity that stands behind both the social and the technical. Often in practise technology is bracketed off and assumed to have a status that is different from humans. This leads to theories of determinism or neutrality because technology is seen as passive, a resource or constraint that is activated by humans. An approach that is premised on the idea that the social is materially heterogeneous must overcome this form of asymmetrical analysis. ANT accomplishes this by identifying the role played by nonhumans in the social order as being as significant as the role that humans play (Callon & Law 1997, p.168).

[3] This insight can be traced back, at least, to Marx when he wrote, "what (humans) are, therefore, coincides with what they produce, with what they produce and how they produce. The nature of individuals thus depends on the material conditions which determine their production." (Marx 1994, p.108)

ANT applies this postulate to contemporary society by asserting that technology is an effect of different human and nonhuman actors and that the form of these objects will remain durable as long as the stable array of relations that make them up hold together. Technology is a network that remains durable as long as every element stays in place and the relations between these elements do not change (Law 2002b, p.93). An example of both the relative durability and the variable trajectory of technology, understood as a network, helps to illuminate this approach.

In his influential article *Do Artifacts Have Politics*, Langdon Winner (1986) writes that renowned New York developer and urban planner Robert Moses intentionally built low overpasses on Long Island (Moses' influence was prominent from 1920-1970) as a means to discourage the presence of buses on his parkways. One consequence of this was that racial minorities and low-income families, the groups that primarily used the 12 foot high public buses, were unable to access Jones Beach, Moses' widely acclaimed public park. The public park, in accordance with Moses' racist beliefs, was to be accessed only by automobile-owning whites of the upper and comfortable middle class. The result, according to Winner, is that many of the monumental structures, these bridges in particular, erected by Moses embody a systematic social inequality that after a time became a part of the landscape (Winner 1986, p.23). This attempt to create inequality by employing material resources was successful, for a while. The network that Moses had created was dependent on a number of diverse elements: relatively expensive automobiles; social classes; racist beliefs, and, concrete bridges. Moses was successful in creating a network that combined all of these elements in a durable network that secured his racist beliefs. It would be easy to imply that technology, in this case automobiles and concrete bridges, determine social inequality. However, by understanding that the desired effect of deliberately constructing low concrete bridges is also the effect of other elements in the network, we can also understand how their durability as political objects can change as the elements in the network change. Moses' racial segregation depended on the distinction between the private car and the public bus and the fact that during a large part of the 20th century it required a large portion of the average income to maintain a car. The concrete bridges were embedded with this interaction (and numerous others) to reflect Moses' desire for racial segregation and inequality. As the relative cost of cars fell, an increasing portion of the classes that Moses hoped would not visit his park are now able to buy and use cars to visit Jones beach. What was at one point a great division cemented by technology became a technology that levelled the access to Jones beach between all social classes (Law 1991a, p.176).

This example identifies the way humans and nonhumans can be combined in intricate social and technical relationships. In this specific case, racism is exerted through a technological network. This particular form of racism is overcome by the variable trajectory of the elements that are juxtaposed in Moses' network. The social is not purely social and the technological is not purely technological. Both contribute and influence each other in a continual process of interaction.

Feenberg critiques ANT on a number of different levels. He begins by attacking the strategy of following the actors, or 'transcendental localism' (Feenberg 2002, p.30), and the results garnered by this methodology. Feenberg dismisses the strategy of following the actors in order to open the 'black box' of technology: "in practise no one is interested in opening the black box of technology to see what is inside" (Feenberg 1995, p.15). The theoretical implications of this strategy are also a problem for Feenberg. By applying a strict operationalism that forbids the introduction of data that is not effective or decisive in the organization of the network, ANT unknowingly applies normative strictures that are incompatible with the CTT. Disturbing normative implications arise because those that are oppressed by technological networks lose their voice, in the sense that the 'losers' perspective in any struggle disappears from view because it cannot be accounted for in actor-network terms (Feenberg 2002, p.31). This mirrors the critique that Hans Radder (1992) makes concerning ANT case studies, and in particular the study of the Portuguese expansion into India by Law (1986a; 1987a; 1987b). Radder makes a plea similar to that of Feenberg: "from Law's account of Portuguese colonial expansion we learn a lot about the (ultimately) successful actors, but hardly anything about the perspectives of the colonized inhabitants of Africa or India" (Radder 1992, p.162).

This critique of the method employed by ANT leads to the next significant problem that Feenberg identifies. ANT does not contain a plausible theory of opposition to the capitalist control of technology. This is because it is humans, and only humans, who can formulate demands based on reflexively examining the technical networks that they are enrolled in. This reflexivity and subsequent demand for a technology that better reflects egalitarian and democratic needs is solely human. On Feenberg's interpretation of the symmetrical treatment of humans and nonhumans found in ANT, the latter cannot explain the ethical dimension of struggle and potential. For Feenberg, opposition and struggle must include a theory of resistance that can oppose the present trend of technical design and suggest an alternative. It is important to Feenberg to retain a strong sense of radical potentiality from which to challenge existing designs. This potentiality is found in the persistent reference to alternative conceptions of nature and individuality which offer a basis for critiquing the totalitarian power of technology. Identifying social conflicts and ills caused by technology enables the critical theory of technology to identify potentialities that are hidden within modern technology. The task of the critical theory of technology is to understand and articulate these potentialities in order to advance a larger human cause on the basis of technology already in existence (Feenberg 2002, p.32-35).

1.3 Comparing CTT & ANT

As was stated earlier, the purpose of this work is to examine and compare these approaches to technology. I believe the results of this comparison will generate an analysis of ANT is that is compatible with the CTT. This rapprochement will be achieved, first, by examining in detail both the CTT and ANT in Chapters Two and Three, respectively. The examination of these two theories is organized by the goal of understanding how both conceive of power in their theoretical understanding of technology and society. Power to control the direction of technological design and innovation, power to maintain stable relations between technology and society, and power to change technology and society must all be accounted for in any examination of technology. Chapter Two will examine the CTT and its concept of power embodied in the technical code, by tracing Feenberg's interpretation of the critical theory of Marx and Marcuse. From these theorists, Feenberg develops the concept of the technical code, a unique and valuable contribution to the critical study of contemporary technology.

Chapter Three will examine ANT in a similar vein, reviewing two significant fields of study from which ANT draws its concept of power. These two fields of study are the 'social construction of technology' (Pinch & Bijker, 1984) and the 'systems' approach developed by historian Thomas P. Hughes (Hughes 1979; Hughes 1983; Hughes 1988). ANT models power through the concept of 'translation', a theoretical model of power that differentiates ANT from the 'social constructivist' and 'systems' approaches. As a conception of power, 'translation' differs significantly from other theories by viewing power not as the cause of social and technical action, but rather as an effect of social and material associations (Latour 1986)[4].

The conclusion of this work constructively addresses the critiques that Feenberg makes of ANT. Accomplishing this task will first require the identification of the common ground of both theories: the idea of the 'sociotechnical'. By conceiving of society and technology as one complex whole instead of impractically separating the two for analysis, both ANT and the CTT mirror one another's belief that "the technology we are currently endowed with could, in another world, be different" (Law & Bijker 1992a, p.7-8). Taking this shared conception of a sociotechnical world as a point of departure for both theories allows both to employ an analysis of the process of 'translation', and both to contribute to identifying the actual point at which the 'technical code' is applied in practise. 'Translation' emerges as a concept that can serve as a means to identify, not only how capitalism encodes technology, but also the ambivalence of technology, and its potential to be re-encoded with the emancipatory values and requirements of a different social system.

[4] Unpacking the concept of translation within the context of this work requires extensive preparatory discussion and will be the burden of Chapter 3.

Chapter Two -The Critical Theory of Technology

This chapter examines the CTT with an emphasis on Feenberg's conception of power, operationalized in the concept of the technical code, in contemporary technological society. The encoding of technology with specific social requirements results in a distinct form of technological rationality that can be discovered by utilizing the concept of the technical code. In our specific social system, capital determines not only the design and function of technology, but also the form of rationality that guides the design process. This can be overcome, though. By identifying the technical code of capitalism in modern technology, Feenberg is able to isolate and critique capitalist technological rationality. Defining capitalist technological rationality as premised on the decontextualization of technology from its social and environmental contexts, Feenberg provides an alternative conception of technological rationality that is characterized by a movement "through reification to reintegration" (Feenberg 2002, p.183). A socialist technical code would recontextualize technology with environmental and social dimensions that are ignored under the technical code of capitalism. The idea of a socialist technical code and an accompanying radical transformation of technology should not be understood as utopian fantasy. Contemporary technology contains the elements that would be needed for this transformation and it is a matter of identifying the point at which technology is encoded that serves as the basis for this transformation.

The technical code provides a concept of power in technological society that recognizes the complexity inherent within it. It is not a matter simply of destroying technology developed within a capitalist society for the purpose of encouraging positive social change. The technical code of capitalism identifies power as residing importantly with those who determine the form and function of technology, not those whose lives are structured by technology. To discover the point at which technological rationality influences technological design decisions that reproduce this social inequality is to discover the point at which social change can be realized without reverting to senseless destruction. Contemporary technology is thus dialectical. It contains within it the power for environmental and social domination *and* the potential to overcome these aspects and reflect a more socially and environmentally responsible set of social requirements.

The purpose of examining technology as dialectical is to combine essentialist insights into the technical orientation towards the world with critical and constructivist insights into the social nature of technology. Technology contains within it not only a decontextualized orientation towards pre-established goals, but also integrative potentials that can take into account the environmental and social effects of technology. Feenberg contends that this dialectical concept of technology breaks with the negative evaluation of technology found in Frankfurt School critical social theory, but also reflects the goal of critical theory to search for a positive moment in modernity that can overcome the disaster of modernity (Feenberg 2002, p.176).

The path that Feenberg follows in his development of the concept of the technical code within the CTT is primarily influenced by the work of Marx and Marcuse[5]. Understanding how Feenberg uses the insights of these theorists to develop the concept of the technical code and the critical theory of technology is the purpose of this chapter. Section one will examine the influence of Marx's work on the critical theory of

[5] Within the context of this work, the works of Marcuse and Marx will be limited to their influence on the CTT. Although both theorists, primarily Marcuse, composed a great number of works that critically approached technology and society and these insights can potentially be contrasted with Feenberg's interpretation of them, this work deals exclusively with the influence of Marx and Marcuse on the CTT.

technology and will explain the concept of 'ambivalence' that Feenberg develops based on Marx's insights. Section two will examine the influence of Marcuse on the CTT. Marcuse's influence emerges into view in the concepts of the technical code and dialectical technological rationality. Section three will then summarise how Feenberg utilizes the technical code to account for a specific form of technological power in contemporary society.

2.1 Marx & The Ambivalence of Technology

The numerous writings that Marx completed contain a number of different approaches to technology. Because of this it is best to assume that Marx's position on technology is ambiguous at best, with a number of different theories and approaches to technology finding support within his writings (Feenberg 2002, p.45-6; see also Mackenzie 1996). Feenberg's goal is not to produce a definitive account of Marx's views; rather he seeks to examine these various positions as they appear or are attributed to Marx in order to derive concepts and approaches that can contribute to a critical theory of technology capable of addressing contemporary concerns (Feenberg 2002, p.46).

Feenberg injects the insights of Marx into the CTT by identifying Marxism as the first theory to unmask the connection between capitalism and technology. Feenberg argues that Marxism, despite this insight, was unable to create a complete socialist politics of technological transformation. "As a critique of capitalism, Marxism shows that politics and technology are inextricably linked, but its concept of socialism fails to take that connection into account" (Feenberg 2002, p.37). Employing a model of the transition to socialism with separate political and technological phases of transition accounts for this failure.

Feenberg writes that despite the diverse number of approaches to technology that Marx took in his writings, he never succumbed to the same fate that Nedd Ludd did by limiting his critique to the 'bad use' of machinery[6] (Feenberg 2002, p.45). Feenberg interprets the critique of the 'bad use' of technology to refer to three problems: 1) what purposes particular technologies are employed to accomplish; 2) how they are employed, and; 3) the way in which technical principles are employed in the design of technology (Feenberg 2002, p.45-46). In order to identify the specific aspect of the critical theory of technology that resonates with Marx's writings, Feenberg examines the three critiques mentioned above in order to derive the concept of 'technological ambivalence', the CTT's debt to Marx.

The first of these bad uses of technology is the 'product critique' that derives from attacking the purpose of technology. This approach focuses exclusively on the ends that technology serves under capitalism while approving of the means. It is neither the technique nor the tool that requires transformation because if the political organization of society is transformed then technology will necessarily reflect this change. Hence, the product critique regards technology as a neutral tool. This view is found in positions that examine technology as an element of the base of society and not inherently predisposed to embody class interests. This position is not a full account of Marx's position though, as support can be found for another position, the 'process critique', that reflects the critique of the way in which technology is employed. Marx frequently attacked the capitalistic employment of technology for causing widespread social and environmental

[6] In *Capital Vol.1*, for example, Marx writes that the Luddite movement was responsible for the "large-scale destruction of machinery." This approach to technology was successfully overcome by "both time and experience" with the result that "the workers learnt to distinguish between machinery and its employment by capital, and therefore to transfer their attacks from the material instruments of production to the form of society which utilizes those instruments" (Marx 1977, p.545-555).

ills. Harming the soil to extract maximum agricultural yields and failing to safeguard the health of the workers can be traced to the capitalist employment of technology (Marx 1977, pp.517-544). The process critique takes into consideration the non-technical effects of the technological production process and contends that this process is therefore not merely a means to an end, but creates an environment for the working population[7] (Feenberg 2002, p.46).

A Marxist approach to technology that is based on the abolition of capitalist property relations, a greater emphasis on the health and safety of the workers and a greater concern for the natural environment mirrors the product and process critique of technology. The problem with this approach, according to Feenberg, is that technology cannot be transformed and democratized through merely a formal change in the ownership of technology because the technological inheritance is specifically adapted to hierarchical control. Undemocratic aspects of capitalist technology that reproduce the capitalist division of labour also need to be transformed, a goal that is incompatible with solely changing the control of contemporary technology or introducing reformative change based on safety or health concerns (Feenberg 2002, p.51).

Feenberg finds a third critique of technology in Marx that overcomes this problem and is reflected in the CTT. This is the 'design critique of technology', an approach that identifies the combination of technological means and social imperatives. By referring to a specific passage in *Capital, Vol.1*, Feenberg is able to show that Marx's work contains a critique of the social purpose of technological design. "Machinery …is the most powerful weapon for suppressing strikes…It would be possible to write a whole history of inventions made since 1830 for the sole purpose of providing capital with weapons

[7] See Jones (1996) for an example of this type of critique.

against working class revolt" (Marx 1977, p.563). This passage asserts that technology is shaped in its design and development by the social purposes of capitalism, and in particular by the need to maintain a division of labour that keeps the labour force safely under control. The CTT is able to derive the concept of technological "ambivalence" by interpreting this particular aspect of Marx and finding support in his work that "technology is a dependent variable in the social system, shaped to a purpose by the dominant class, and subject to reshaping to new purposes under a new hegemony" (Feenberg 2002, p.48).

The 'ambivalence of technology' is the concept Feenberg uses to identify the actual base of technological transformation within contemporary technology. Technology developed within a capitalist system reflects the social requirements of capitalism. These requirements are introduced at some point during the design process. To identify the point at which these requirements are embedded in technological design is to identify the point at which technology is ambivalent towards a number of different social systems.

The Marxist conception of the transition to socialism needs to incorporate both the political and technological base that it inherits from capitalism[8]. Focusing exclusively on technology, the concept of ambivalence concerns not the different ends that can be served by the existing technology, but what new technological means it may produce. Technology can be reshaped as machines developed under capitalism are employed to

[8] Feenberg admits that emphasising technology and politics equally within a transformation to socialism cannot be qualified as Marxist in the usual sense and will be greeted with scepticism by Marxists who turn to political economy for the serious business of social critique. However, "an exclusive emphasis on political economy tends to overestimate the rationality and coherence of capitalist strategies and underestimates the significance of resistances, innovations, and reforms in every domain except class struggle, where, unfortunately, there is little to report" (Feenberg 2002, p.23).

produce a new generation of machines adapted to socialist purposes (Feenberg 2002, p.53). The theory of ambivalence serves as a source of resolution between political realism and utopia by,

> identifying the raw material of socialism among the inheritances of capitalism. It asserts the possibility of bootstrapping from capitalism to socialism. As far as technology is concerned, it is difficult to imagine an alternative to an ambivalent process of change. A whole new technology cannot spring pure from the sweaty brow of the proletariat as Athena did from Zeus's forehead. (Feenberg 2002, p.53)

According to Feenberg, the Marxist conception of the transition to socialism fails to take into consideration the connection between capitalist technology and the transition to socialism because it relies on a two-phase conception of the transition to socialism. The "two-phase" conception of the transition became significant during the late 19th century when socialist parties rationalized moderate strategies of short term reform in the present while holding out for the 'purely rhetorical promises' of the utopian "higher phase of socialism" (Feenberg 2002, p.39). A theory of the ambivalent employment of the technological inheritance of capitalism cannot be found in the work of Marx because this would be achieved in the higher phase of transition to socialism. As a result of this, Marx's concept of the transition to socialism lacks a connection between the theory of the socialist state in the first phase of socialism and a theory of the transcendence of the division of mental and menial labour in the higher phase of socialism (Feenberg 2002, p.59).

This problem can be seen in the product and process critique of technology. The notion that the transition to socialism can be accomplished by changing who controls technology and by introducing measures that limit detrimental health and environmental effects does not overcome the capitalist division of labour. Although these reformative aspects of technology reflect the first stage of the transition to socialism, it is essential to also incorporate, at the same time, the higher phase of the transition to socialism, the end of the capitalist division of labour. Socialist emancipation cannot be accomplished by implementing the policies, no matter how socialist, of those who simply inherit the technological base of capitalism. Every such person then finds themselves in the exact position formerly held by the capitalist, obliged to use the same means of repression to extract labour power from an unwilling working class (Feenberg 2002, p.60). The two phases of socialism, reinterpreted to mean from Feenberg's perspective, political transformation in the first phase and technological transformation in the second phase, reflects a theoretical tension in Marx's concept of technology and transition[9]. Feenberg presents an alternative conception of the transition by condensing the two phases into an extended period of "democratic struggle over technology and administration" with the aim of democratizing the power base of capitalist technology at the same time as democratizing the administrative and governmental power base of capitalism (Feenberg 2002, p.60-61). This new approach to the transition to socialism can only be accomplished by applying a critical theory of technology that recognizes and incorporates the ambivalence of technology at all levels of transition.

2.2 Marcuse - The Technical Code & Dialectical Technological Rationality

Feenberg's integration of Marxism into the critical theory of technology is necessary in accounting for the relationship between technology and society. Reducing technology to

[9] Feenberg uses the example of the USSR to show how a state can be trapped between socialist ideology and capitalist heritage. The Soviets were unable to carry out socialism properly because they replicated the control aspects of capitalist technology. The Socialist regime could only implement policies where these were compatible with capitalist technology, thus confirming Feenberg's thesis that socialism cannot be imposed by transforming law and government administration alone (Feenberg 2002, p.60).

an instrumental tool[10] results in an incomplete concept of both social and technical transformation. The design critique of technology and the ambivalence of technology are based on the idea that technologies contain social and technical functions. The design critique explains how technology is influenced by social and not strictly technological, imperatives. The theory of ambivalence asserts that technologies influenced by social factors are subject to social change. Incorporating Marx's notion of the potential for a transition to socialism by using the technological means at hand necessitates a radical alternative to instrumental Marxist theories of technology (Feenberg 2002, p.63-4). This is accomplished by utilizing the insights of Marcuse's critique of technological rationality and reconceptualizing these insights into a theory of technological power that recognizes a dialectical concept of technological rationality.

Defining technology as having two dimensions that reflect differing interpretations of technological rationality allows Feenberg to identify the basis of technological and social change within the critical theory of technology. "Once rationality is treated as a social phenomenon, its concrete sociological forms are open to study" (Feenberg 2002, p.67). The CTT seeks to undertake a 'rational critique of rationality' to isolate the dominant form of technological rationality, in order to show that this is only one possible form of rationality amongst others (Feenberg 2002, p.69).

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[10] By rejecting technology as an instrumental tool, Feenberg also rejects the notion of instrumental rationality. This idea is essential to a critical theory of technology that attempts to overcome the inherent problems of contemporary technology, primarily the capitalist division of labour and top-down control. This insight can be linked back to the work of Marcuse who examined the historical development of reason and technological rationality and how this came to be the logic of domination (Marcuse 1964, p.123). Marcuse's insight that, "the science of nature develops under the technological a priori which projects nature as a potential instrumentality, stuff of control and organization. And the apprehension of nature as (hypothetical) instrumentality precedes the development of all particular technical organization" (Marcuse 1964, p.153) is the conclusion that Feenberg uses to critique instrumental conceptions of technology.

The CTT attacks capitalism by attacking its forms of rationality. In order to critique the apparent neutrality of capitalist technology, the CTT must undermine the standard of rationality that defines it (Feenberg 2002, p.163-165). The design critique of technology and theory of ambivalence found in Marxism relate the values embodied in technology to a social hegemony, "but what depends on a social force can be changed by another social force – technology is not destiny" (Feenberg 2002, p.64). Feenberg associates this concept with the work of Marcuse, whose work is one of the most significant approaches to modern forms of domination that "treated technology as an expression of the historical development of the dominant paradigm of rationality" (Feenberg 2002, p.64-5).

Marcuse begins this task by clearly identifying the bias that exists in modern capitalist technological societies. "Scientific-technical rationality and manipulation are welded together into new forms of social control. Can one rest content with the assumption that this unscientific outcome is the result of a specific societal application of science?" (Marcuse 1964, p.146) Both Marcuse and Feenberg identify this feature of modern society and argue that because technology concentrates power in the hands of the few, it should be subject to the same critique that Marx applied to the market. "Like market rationality, technological rationality constitutes the basis for elite control of society…This control is not simply an extrinsic purpose served by neutral systems and machines but is internal to their very structure" (Feenberg 2002, p.66).

Feenberg's concept of capitalist technological rationality is dependent on the connection that Marcuse makes between formal universal rationality and domination. Formal rationality imposes a universality that abstracts from the whole, not towards its potentiality, but rather towards its form. "Rationality here calls for unconditional compliance and coordination, and consequently, the truth values related to this rationality imply the subordination of thought to pre-given external standards" (Marcuse 1941, p.147). The result of this is that technology is pre-disposed to meet capitalist standards of efficiency and organization at the expense of a potential transcendent reality that technology could mediate. This form of technological rationality also infiltrates the attitudes of the people of capitalist technological society by dissolving "all actions into a sequence of semi-spontaneous reactions to prescribed mechanical norms (that is) not only perfectly rational but also reasonable" (Marcuse 1941, p.143).

Formal universals decontextualize their objects from their social and natural contexts across both time and space. "Instead of transcending the given towards its essential potentialities, this type of universality classifies or quantifies objects in terms of the function that they can be made to serve in an instrumental system imposed on them from without…Formal reason is biased toward the actual, what is already realized and available for technical control" (Feenberg 2002, p.169). This bias appears in technology through the inability of those who design and standardize technology to grasp the history and social contexts within the process of technological innovation and development. Technology can only be used and adapted for social domination, not transformed to reflect the realization of the potentialities in the context of a different society (Feenberg 2002, p.169).

Despite Marcuse's influential insights toward a critical theory of technology, Feenberg finds it difficult to recognize in Marcuse a complete critical theory of technology that provides an alternative conception of technological rationality.

Marcuse's theory offers no basis for understanding how the dominated might avoid domination, how to block the inevitable one-dimensionality of capitalist technological rationality. Marcuse seems to admit that all forms of resistance can be absorbed by capitalism. Offering an analysis that differs from Marx's original insights concerning the relationship between capitalism and the society, Marcuse correctly identifies a feature of contemporary capitalism that was not obvious in Marx's time. Capitalism no longer offers minimal compensation for alienation and misery; it delivers the goods like never before to a working class that is incorporated into the system (Marcuse 1989, p.227). Marcuse's critical theory of technology ends at an impasse by describing the system of capitalism as an unbroken chain that is formed by authoritarian management, technology adapted to its needs, and a ready supply of consumer goods. Opposition to this system is virtually non-existent and thus "the theory subverts itself by cancelling the idea of transcending action and appears to reinstate the fatalism of a Heidegger or Ellul" (Feenberg 2002, p.72).

The textual evidence that Feenberg uses to come to this conclusion can be found in the preface to *One-Dimensional Man*. Feenberg contends that Marcuse wavers in his critical approach to technological society because as Marcuse writes, "advanced industrial society is capable of containing qualitative change for the foreseeable future" (Marcuse 1964, p.xv). Although forces exist that may break this containment, the power of advanced industrial society is dominant. Faced with this impasse, Marcuse suggests that perhaps only a catastrophic accident may alter the situation (Marcuse 1964, p.xv; see also Feenberg 2002, p.72).

Feenberg seeks to preserve the essential insights of Marcuse by arguing that his critical insights lack a theory of technological hegemony capable of explaining in detail the connection between technology and rationality. By providing a theory of technological hegemony, Feenberg is able to offer a dialectical concept of technology that reflects the need to transcend contemporary social and technical arrangements with an alternative form of technological rationality. Avoiding the fatalism of Marcuse requires a theory of hegemonic mediations responsible for the problems that he appears to blame on technology (Feenberg 2002, p.74). This is accomplished through the development of the concept of the 'technical code'. The technical code is Feenberg's means of explaining technological power in contemporary society.

Utilizing the work of Marcuse, Feenberg builds up to the concept of the technical code by introducing a 'dual aspect' theory of ideology/technology. This concept treats hegemonic and cognitive functions as reciprocal aspects of one underlying source. In this case that single source is capitalism. Both the social power of capital, and technical knowledge, expressed through capitalist technological rationality, are integrated in a concept of social and technical power. To grasp this concept involves an examination of the function of rationality in modern hegemonies. An effective and determining hegemony is one that is not imposed by force through a continuing struggle between resistant agents and a system. To succeed, a hegemonic system of rationality should be reproduced unreflectively by the standard beliefs and practises of the society that it dominates. For the centuries that pre-dated the rise of capitalism, religion and tradition exercised the role of hegemonic power in this way. Today, forms of rationality supply the hegemonic beliefs and practises that were at one time provided by the church and the community (Feenberg 2002, p.75).

Capitalism is unique in that its hegemony is largely based on reproducing its power through technical decisions. This argument can be traced to the difference between pre-capitalist and capitalist relations of production. In pre-capitalist societies, the labour process was enveloped in regulations and responsibilities stemming from the ownership of tools and the formation of natural communities based on skill and need. Capitalism frees itself from these limitations by building workforces and markets out of atomized individuals. Refusing to recognize aspects of social organization based on traditional or communitarian ideals, the capitalist has a great deal more freedom of action. Feenberg calls this freedom of action the capitalist's "operational autonomy". All strategies imposed from the position of the capitalist must reproduce his/her operational autonomy at the expense of other potential strategies that would reflect different concerns and interests. Operational autonomy is not a property of individuals per se, it is the property of the capitalist organization of the technological elements of society (Feenberg 2002, p.75-76).

Capitalism works to preserve and expand its operational autonomy and this goal is gradually incorporated into the standardization of procedures and artefacts that establish a framework in which daily technical activity serves the interests of capitalism.

> Capitalist social and technical requirements are condensed in a "technological rationality" or a "regime of truth" that brings the construction and interpretation of technical systems into conformity with the requirements of a system of domination. I will call this phenomenon the social code of technology or, more briefly, the technical code of capitalism. Capitalist hegemony, on this account, is an effect of its code. (Feenberg 2002, p.76)

The technical code of capitalism is not just the rule that guides technical choices. It also exists as a form of technological rationality and logic that ensures the preservation of the capitalist's operational autonomy. In order to exist, organizations must encode their technological base by binding technology to hegemonic social requirements. This is accomplished in the design stage of technology. Technological innovations are built up from tangible technical elements – springs, levers, gears, etc. These elements are placed together to create a technological artefact. Technology, during the design process, is decontextualized from its social context and encoded with the social requirements of capitalism. These requirements reflect and impose a system of top down control before they are socially contextualized in actual practise.

An example of this encoding can be found in Smythe's (1973) description of television technology, which he argues is specifically suited for a capitalist system:

> Existing TV techniques had been developed under capitalism to make possible the sale of motion pictures and other commodities to people in their homes. At the time when TV was developed in capitalist countries it would have been possible to design a two-way system in which each receiver would have the capability to provide either a voice or voice-and-picture response to the broadcasting station. But for its purposes, capitalism needed only a one-way system and this is what was developed. (Smythe 1973, p.231-232).

The technical code of capitalism identifies a process of technological invention that is not entirely determined by technical means. Decontextualized technologies are encoded to meet social constraints. Thus, a complete definition of technology employing the technical code includes the idea that technologies are more than a sum of their parts; they also embody a social purpose in the very selection and arrangement of technical elements from which they are built.

The embodiment of specific purposes is achieved through the "fit"

> of the technology and its social environment. The technical ideas combined in the technology are relatively neutral, but one can trace in it the impress of a mesh of social determination that pre-construct a domain of social activity in accordance with certain interests or values. (Feenberg 2002, p.78)

The technical code of capitalism can be defined as the general rule for correlating the social and the technical into a single technological artefact. The ambivalence of technology can be found when one descends towards the foundation of technological development and discovers relatively ambiguous technical elements that can serve a number of social purposes. Identifying the ambivalence of technology supports the notion that the technical code is the primary source of power in modern technological societies. "A technical code is needed to bind technological applications to hegemonic purposes since technique can be integrated to several different hegemonic orders. This is also why new technologies can threaten the hegemony of the ruling groups until it has been encoded" (Feenberg 2002, p.79).

By applying a dual aspect approach to technological rationality, the idea that knowledge and power are two effects of a single source, the relation between technical knowledge and society is made clearer. Introducing a terminology that solves the problem of critiquing knowledge/rationality as a projection of social power without reverting to fatalism or determinism is achieved by identifying the connection between technology and social hegemony. The technical code is a means of understanding how both of these factors are co-ordinated in technological application (Feenberg 2002, p.80).

To remedy his critique of Marcuse that his theory does not present a theory of resistance to dominant forms of technological rationality - Feenberg constructs a concept of dialectical technical rationality. This feature of the CTT again makes use of Marcuse's theory of technological rationality, but also identifies the transcendent potential of contemporary technology by identifying the means at hand that can influence positive change.

The CTT depends on a distinction between what Feenberg calls ‘primary’ and ‘secondary’ instrumentalizations of technology (Feenberg 2002, p.175). The first of these, the primary instrumentalizations of technology, mirrors Marcuse’s critique of formal technological rationality. Technological rationality is predisposed to decontextualize the technical object from its immediate social context and thus impels technology towards its immediate use and not its potentiality. Feenberg details the moments of primary instrumentalization in the separation of the technical object from its immediate context; in the reduction of all technical objects and the subjects who use them to their useful aspects; and in the protection of the technical object and not its subjects from the immediate and long-term consequences of technical action (Feenberg 2002, p.178-183).

Because technology is not simply an orientation toward the world, recognizing only the primary instrumentalization of technology neglects the social and environmental context of technological use. Feenberg identifies and contrasts the moments of secondary instrumentalization. Instead of separating the technical object from its immediate context, secondary instrumentalization proposes that technology be reintegrated with humans and nature. Instead of reducing objects to their useful aspects, aesthetic and ethical qualities can be incorporated into their design. Instead of separating the technical object from its immediate consequences, human users can democratically decide the future and fate of their societies by examining the use and immediate and long-term effects of technology (Feenberg 2002, p.178-183). The description of the car used in the introductory chapter can serve as an example of this approach. Accounting for the secondary instrumentalizations of the car would require designers, manufacturers and consumers to recognize the complexities that stand behind the car and attempt to account for these. Instead, most people understand the car as simply a primary instrumentalization and concern themselves with its performance and how it serves pre-existing immediate needs.

The theory of the secondary instrumentalization of technology is a theory of the way in which "the skeletal primary instrumentalization takes on body and weight in actual devices and systems in a social context" (Feenberg 2002, p.175). Technology contains both the decontextualizing primary instrumentalizations and the integrative secondary instrumentalizations. Although in practise these levels are inseparable, Feenberg identifies them as analytically distinguishable by arguing that technology is dialectical. In this sense, technology can be understood as oriented towards an existing reality, or it can be understood as a tool that can potentially liberate humankind by influencing its design and use towards an as yet unfulfilled transcendent reality. A full account of technology must include the secondary instrumentalizations of technology denied at the primary level. The CTT, by employing instrumentalization theory, is able to identify the technological resources at hand that realize the potential for technological transformation (Feenberg 2002, p.176). "The dialectics of technology is thus not a mysterious 'new concept of reason' but an ordinary aspect of the technical sphere, familiar to all who work with machines" (Feenberg 2002, p.177).

2.3 The Critical Theory of Technology

The CTT and its concepts of the technical code and the ambivalence of technology provide an account of technological power that seeks to identify why technology takes the form that it does. The technical code of capitalism is applied to contemporary technology to determine its function and form. Capitalist hegemony does not rely on a particular technique of social control, but more fundamentally on the technical reconstruction of the entire field of social relations within which it operates (Feenberg 2002, p.183). This fact not only applies to capitalism, it applies to any hegemonic force. Feenberg uses the instrumentalization theory of technology to provide a model of socialism based on a socialist technical code. A socialist technical code would emphasise the reintegration of the secondary instrumentalizations of capitalist technology. Ecological, medical, aesthetic, urban planning, and democratic considerations that the capitalist technical code regards as problems external to the process of technological design and use would be reintegrated as engineering objectives into a more humane and environmental responsible technology determined by a socialist technical code (Feenberg 2002, p.183-184).

This is the potential that is embodied in contemporary technology, but the reality of technological society is quite different than this conception. Technology takes the form that it does because capital enacts oppressive relationships through the secondary instrumentalizations of technology. Because capitalist hegemony is dependent on a specific form of technological rationality, it reduces technology to its primary instrumentalization to produce a form of technical rationality that is based on decontextualization, calculation and control. The result of this is that the definition of technology is reduced to include only this primary instrumentalization and other aspects and effects of wide-spread technological mediation are suppressed by relegation to non-technical concerns (Feenberg 2002, p.177).

The dialectical concept of technology is blocked by the capitalist technical code. The need to incorporate the social requirements of capital into technological design is recognized and carried out by the technical code of capitalism. This code creates technologies that reproduce capitalist power by employing fragmentation, decontextualization, and the capitalist division of labour. The technical code also forms a type of universal knowledge defined by a specific form of technological rationality. Together, these social and technical elements determine a form of technology that is based on top-down control and results in environmental and social problems that cannot be solved in the current social or technical order. Capitalism determines knowledge of what technology is, in a manner that blocks any attempt to reintegrate the secondary instrumentalization of technology.

Chapter 3 – Actor-Network Theory

The previous chapter detailed the approach that Feenberg takes to technology by examining the concepts of ambivalence and the technical code with the CTT. This theory and its elements contain a definitive reason why contemporary technology exists as it does. Capitalism determines the form and function of technology by encoding it with a capitalist technical code that ensures both the technical and social requirements of capitalism are embodied in technological artefacts. The technical code not only determines the form and function of technology, it also blocks the inherent potentiality of current technology to meet more humane and environmental requirements by naturalizing a narrow definition of technological rationality. This chapter seeks to examine ANT in order to identify its concept of power: 'translation'. Deployment of the concept of translation does not explicitly seek to answer why technology takes the form that it does; rather, it seeks to identify how the social and technical remain durable and expand over time and space.

Before examining 'translation' as a concept of power, it is important to examine ANT in more detail. Examining ANT in this context will entail tracing the influence of two similar approaches to technology that ANT reflects: social constructivism (Pinch & Bijker 1984) and the systems approach of Thomas P. Hughes (1979; 1983; 1988). The point of this digression is twofold: first, it introduces and accounts, from within the field of society and technology studies, the specific methodological and theoretical principles of ANT; and second, it details the theoretical background that provides the point of departure for the concept of translation as it is developed within the actor-network approach.

3.1 The Social Constructivist Position: Pinch & Bijker's Contribution

Deriving from the sociology of science and the sociology of technology, social constructivism has influenced the growing field of technological studies[11]. In an influential article, Pinch & Bijker (1984) lay the groundwork for this approach by synthesizing the empirical programme of relativism (EPOR) found in the sociology of science and early attempts of applying a social construction of technology (SCOT) model (Pinch & Bijker 1984, p.400).

The EPOR is an approach that has demonstrated the social construction of scientific knowledge in the 'hard sciences'. This approach is best known as the strong programme approach of the sociology of scientific knowledge (SSK).[12] Unique to this approach is the focus on the empirical study of contemporary scientific discoveries and innovation, and in particular the controversies that arise during the process of closure that concludes these debates. This approach to science is premised on the understanding that scientific knowledge is as contestable as other forms of knowledge. In order to understand how it is that specific types of scientific knowledge are taken to be true one examines elements external to science itself that may be responsible for the growth of particular forms of scientific knowledge. This approach can be grasped quickly with the aid of Pinch & Bijker, who identify three successive stages in the explanatory aims of EPOR: interpretive flexibility, closure mechanisms and the relation of the closure

[11] For the sake of brevity I will only examine the claims made by Pinch & Bijker (1984); for a review of other works in this field see Bijker, Hughes & Pinch (1987) and Pinch (1988).

[12] This approach is best acquainted with the Edinburgh school of the sociology of scientific knowledge (SSK). This approach to the sociology of scientific knowledge adheres to the following principles: 1) It should be concerned with the conditions which bring about belief or states of knowledge; 2) It is impartial with respect to truth and falsity, rationality and irrationality, success or failure. Both sides of these dichotomies require explanation; 3) It should be symmetrical in its style of explanation – the same types of cause would explain true and false beliefs (the principle of symmetry), and; 4) It should be reflexive. Its patterns of explanation would have to be applicable to sociology itself (Bloor 1976 [1991], p.7).

mechanisms to the wider socio-cultural environment. The interpretive flexibility of scientific facts is displayed by showing that scientific findings are open to more than one interpretation. Multiple interpretations are quickly eliminated by a scientific consensus as to what the truth is in any particular instance; this represents the closure, or stabilization mechanisms of EPOR. The third aspect, the impact of these closure mechanisms on the wider social environment, had yet to be carried through in any study of the contemporary sciences. EPOR is a part of the effort to study and understand the content of the natural sciences and scientific knowledge in terms of social construction by studying the closure mechanisms used to create consensus amongst controversy (Pinch & Bijker 1984, p.409-410).

In SCOT, turning from science to technology, the developmental and stabilization processes of a specific technology is described as multi-directional. In historical hindsight (using a technological determinist or neutralist position) it is easy to collapse the process of technological development into a simple linear model[13], but this would miss the primacy of approaching these stages of technological development as not being the only possible ones. If the multi-directional model is applied it is possible to investigate why some designs fail while others succeed, thereby exposing more clearly the interpretive flexibility of technology (Pinch & Bijker 1984, p.411). In this model the defining role is played by social groups that are concerned with the technology itself. For it is the social groups concerned with the development of a technological artefact who decide which problems are relevant. The meaning given to any particular technical object is only achieved when a problem is defined and answered by a specific social

[13] Pinch & Bijker describe the linear model of technological development as occurring in six consecutive stages: Basic research, applied research, technological development, product development, production and usage (Pinch & Bijker 1984, p.405).

group. These social groups can subsequently be further broken down and defined; for example Pinch & Bijker in describing the development of the bicycle find it necessary to break down the social group 'cyclists' into separate social groups of 'female cyclists' and 'sport cyclists', each having specific interests. For example, sport cyclists who raced bicycles had specific problems that needed to be solved (speed). These problems differed from the problems identified by female cyclists who were concerned primarily with maintaining a certain level of modesty while riding the bicycle. The goal of this is to have a detailed description of all the relevant social groups in order to better define the function of the artefact with respect to each group (Pinch & Bijker 1984, p.414-415). The identification of the relevant social groups and their interests exposes a number of conflicts: conflicting technical requirements, conflicting solutions to the same problem, and moral conflicts. This model does not merely describe the development of technology as a linear process, it highlights the multi-directional character of such developments as well as revealing the interpretive flexibility of technology and the role that different closure mechanisms may play in the stabilization of any specific technology (Pinch & Bijker 1984, p.419).

Thus, Pinch & Bijker describe an integrated approach to the social construction of technology by emphasizing three important aspects of the synthesis between SCOT and EPOR. 'Interpretative flexibility' emphasizes the point that technology is culturally and socially constructed and interpreted as well as implying that the design process itself is flexible – there is not one possible or best way to design a technical object (Pinch & Bijker 1984, p.421). When dealing with technology, the process of stabilization or the closure of debate surrounding a technological artefact is best understood by analyzing the stabilization of the artefact across a number of social groups, by interpreting the closure mechanism. Pinch & Bijker describe two such mechanisms: rhetorical closure and closure by redefinition of the problem[14]. Both mechanisms can appeal to the interests of the relevant social groups and it is those social groups who determine the final form of the technology in question (Pinch & Bijker 1984, pp.424-428). Examination of the relevant social groups also appears to lead to a conclusive decision concerning the third aspect of this synthesis, attempting to understand the relation of a technological artefact to the larger socio-cultural environment. By focusing on the meaning attributed to a technological artefact by a specific social group it is possible to trace this meaning to a larger socio-cultural or political situation which may influence the meaning given to an object. In this way, the social constructivist model of understanding technological development and stabilization seems to offer an account of the operationalization of the relationship between the larger socio-cultural context and the content of technology (Pinch & Bijker 1984, p.428-429).

The similarities between ANT and the social constructivist approach are many: the inherent interpretive flexibility of the technological artefact itself, a dismissal of the linear model of technological development, and an emphasis on empirically analyzing all of the actors that influence the technology in question. However, ANT does differ from the social constructivist perspective in a number of key ways that, when taken together, help to reveal ANT as a distinct and unique approach to analyzing technology, separate from the social constructivist approach.

[14] Rhetorical closure refers to the method by which the relevant social groups propose the technical problem be solved. Advertising can play an important role in this process. The other possible means of closure, closure by redefinition of the problem, means redefining the key problem with respect to how the artefact is the solution.

The most significant point of departure for ANT on this matter is a disagreement with what Law refers to as social reductionism, the view that it is social factors and social factors alone that explain the growth of technological systems (Law 1987b, p.229). Social reductionism as an explanatory strategy tends towards the assumption that stable social factors lie behind and outside the technology and direct its evolution. These social factors are taken to be unchanging, and consequently, are left substantially unanalysed (Law 1987b, p.230). The alternative to this position is to adopt a position in which social factors are not privileged and to undertake the investigation of technology with a view that social factors are not the sole determining force in technological development[15]. Rather, the actor-network approach works out the implications of assuming that the stability and form of technological artefacts "should be seen as a function of the interaction of heterogeneous elements (both social and technical) as these are shaped and assimilated into a network" (Law 1987a, p.113).

The second significant difference in the ANT approach follows the first in questioning the social reductionism of social constructivism. By undertaking a study that follows the actors or technological system builders (Law uses the term 'heterogeneous engineers'), ANT understands these system builders to be constructing simultaneously the social and the technical, the 'sociotechnical' (Law 1987b, p.231; see also Callon & Law 1989; Law & Callon 1988). The actor-network approach finds that social interests do not stand outside and behind technological development; rather, they are created in much the same way that the technology is created. A way to understand this is to adopt the analytical principle of *generalized agnosticism* (Callon 1986b, p.200) that eliminates

[15] See Callon & Law (1982) for an example of how social interests are not to be seen as background factors but as attempts to define and enforce the institutions, groups or organizations that exist from time to time in the social world.

the need to refer to macro-social categories by examining these categories as an effect of micro-level interaction:

> The force of our traditional sociological view obviously depends entirely upon the notion that the professional sociologist has a more warrantable account of social interests than those whom he or she studies and that expressions by actors of their own interests or those of others must at best be seen as data for the hidden version of events that is visible only to the sociologist…The role of (ANT) becomes that of discovering the methods by which actors and collectives articulate conceptions of the natural and social world and attempt to impose these on others and the extent to which such attempts are met with success (Law 1986b, p.3)

The best way to clearly show these differences is to revisit the case study mentioned in Chapter 1, the development of the electric car (VEL) in France. This project was first presented by a group of engineers working for EDF (Electricite de France – the public electricity utility in France) in the early 1970's. The genesis of this project was an evaluation of the trajectory of the development of different electrochemical batteries created by EDF engineers (Callon 1987, p.85). Their predictions and conclusions showed that properly developed lead accumulators can be used in public transportation until 1982. The year 1982 will mark the beginning of zinc/nickel accumulators and the zinc/air circulation generator allowing top speeds of 90 Km/h. In 1990 the fuel cell will be available, based on the trajectory already in place, for use in all publicly and privately owned vehicles (Callon & Latour 1981, p.288). Of equal importance in this project was the redefinition of French society by EDF as a, "society of post-industrial consumers who were grappling with new social movements. The motorcar occupied a position that was highly exposed, for it formed a part of a world that was under attack" (Callon 1987, p.85). The EDF determined a specific history of French society and defined what was coming next: the all-out consumption of the post-war years is doomed. The direction of future production must take into account the happiness and quality of life of the French people. In this way, the EDF placed the history and evolution of French industrial and consumption society as a whole in a 'black box'[16] (Callon & Latour 1981, p.287). The social factors that were important were isolated and made significant, along with the technology itself, in a proposed sociotechnical network.

The EDF also redefined Renault, the leading automobile manufacturer in France and a leader of European industry, by depicting their role in this society as simply the manufacturer of the new chassis and car bodies. Renault will no longer be a powerful company. It will be reduced to the level of a modest company that has limited participation in assembling the VEL (Callon 1987, p.86). As well, the federal government, as defined by the EDF, will be responsible for enlisting different ministries to subsidize municipalities that show interest in developing electric public transportation. Municipal governments were depicted as solely city councils whose task it was to develop a public transportation system that does not increase the level of pollution (Callon 1987, p.94). The technical elements that were needed to run the VEL were determined: the zinc/air accumulators, lead accumulators and fuel cells with their associated entities including catalysts and electrons. These technical elements were not given in the order of things; they were determined previously by the group of engineers working on energy conversion[17] (Callon 1987, p.86).

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[16] See Chapter 1 for an explanation of the term 'black box'. In this case a black box is a collection of disorderly and unreliable entities that form into an organized whole. When many elements are made to act as one, it is a black box (Latour 1987, p.131). See also Whitley (1972) for further discussion of the'black box' theory in the sociology of science.

[17] See Callon (1981) for a detailed study of how multiple interpretations of what constituted a fuel cell were negotiated and stabilized into a working black box that was to become known as the developmental model for the fuel cell and subsequently the VEL.

The EDF had black boxed, or in the language of Callon, simplified, complex networks into workable and manageable actors. Social factors in this case were not seen as standing outside and behind the technology itself; the society that was needed in order for the VEL to be successful was created and simplified in much the same way that the technological specifications were. The VEL, if successful, would be a black box that contained a number of other black boxes, reiterating what Callon & Latour (1981) believe to be true of macro-structures: "Macro-actors are just micro-actors seated on top of many (leaky) black boxes" (p. 286). By qualifying the black boxes as leaky, Callon and Latour are rephrasing what Law (1992) believes to be true of all macro-structures, that for a time, if they perform and act as a single block[18], the complex networks that make them up disappear; but, all punctualization and simplification is precarious and any macro-structure can degenerate into a failing network (p.385). This is exactly what happened to the VEL: instead of maintaining the proposed simplification process, the world was rendered more complex by stigmatizing the reality created by the EDF (Callon 1987, p.94).

The black boxes that the VEL was seated upon were opened by the concerted efforts of Renault and by the unpredictable behaviour of the defined technical and social actors. These actors were not satisfied, or did not perform, the role that they had been given in the sociotechnical scenario proposed by the EDF. Renault attempted the task of de-associating all the association made by the EDF. Each interaction was tested and every calculation redone in order to open all the black boxes proposed by the EDF

[18] If a network is seen as a single block, or an actor, it is punctualized according to the terminology of ANT. Network relations that are widely performed are those that can be punctualized. For example, the traditional automobile is a punctualized network of relations because the complexity of interactions between pistons, transmission, oil exporting countries, financing options and the infrastructure of roads is masked in the performance of this particular network (Law 1992, p.385).

(Callon & Latour 1981, p.291). Renault successfully showed, by collecting and interpreting data and redefining the results that EDF constructed, that the EDF prediction of a post-industrial age was simply a minor problem that could be overcome. The social criticism levelled at the traditional car was not as drastic as EDF claimed it was; instead, it was simply temporary and local dissatisfaction with the car industry's lack of dynamism and the poor state of public transportation. In the three years since the project was first proposed, the protest movement had dissipated, recession was looming large and a greater focus was needed for reindustrialization, not a move towards post-industrialization (Callon 1987, p.97). Renault also questioned the technology of the VEL by showing that the zinc/air accumulators were a shaky venture lauded by only a handful of researchers whose loyalty was with the EDF. As well, Renault introduced the fact that if the VEL was to become the standard of transportation in France the entire national infrastructure of service stations would need to be transformed into stations where used electrolytes could be changed periodically. Renault proposed a gloomy future of uncertain strategies and conflicting interests between industrial groups in contrast to the idealized world of the EDF (Callon 1987, p.91).

Here we can clearly see the differences between the actor-network approach and social constructivism. Whereas social constructivism examines the interests of social groups as the determining factor in the development and closure of a technological artefact, ANT proposes that we should analyse how these social interests are both constructed and juxtaposed with other entities in the network. For the VEL to be successful, the post-industrial society that was predicted by the EDF engineers is just as important as the successful working of the technical elements that make up the zinc/air accumulators. Social interests and technical logistics are constructed and placed in a network simultaneously so that the network of social interests and the network of technical elements combine into a sociotechnical network that does not privilege either social or technical factors.

Taken a step further, ANT argues against essentialism of any kind by assuming, prior to empirical investigation, that nothing is given in the order of things, including macro-social structures that may influence the design or evolution of technology. This is termed 'relational materiality' by Law (1999): the understanding that entities have no inherent or essential qualities, but take their form and acquire their attributes as a result of interaction with other entities. The result of this is that all divisions (big or small, agency or structure, truth and falsehood) between entities, prior to investigation, are dismissed. If such divisions or distinctions exist, they should be seen as an effect or outcome of interaction (p.3).

If it appears that a macro-structure determines the outcome of technological design, the question then should be: How was this actor able to grow to be a macro-structure? And, more importantly what processes and materials assist in this growth? This is the study of 'translation'. No actor can maintain power over another, in the ANT view, except by means of translation (Callon & Latour 1981, p.280-281). For EDF to grow over time and space, and subsequently for Renault to shrink, the predicted and pre-defined interactions between technical and social entities proposed by EDF would have to hold. Renault is not by nature a large and powerful corporation; it achieved this position by networking countless simplified entities. The way in which these entities are made to hold their place in this, or any, sociotechnical network is through translation. Translation is the way in which one actor is able to make all other actors go through it in order to achieve its goals.

3.2 The Systems Approach to Technology: The Seamless Web

ANT takes, according to Callon, the systems-inspired analysis and insights of Thomas P. Hughes one step further (Callon 1987, p.101). In his seminal study of Edison and the electrification of America (Hughes 1979; Hughes 1983) Hughes adopts a systems metaphor to explain the rise of technological development, innovation and implementation. Key to Hughes' analysis is the notion of the 'seamless web', an idea that arose through following the historical records of Edison. Hughes discovered that importance should be given, not to the inventor exclusively, but also to the evolution of the total system of production. In his study of Edison, Hughes is careful to explain the importance of individuals such as Samuel Insull and S.Z. Mitchell[19] as well as the materials available at Menlo Park as equal parts in the same system:

> The availability of these varied talents helps explain the encompassing character of Edison's concept of a system. Furthermore, they were supported by a broad array of expensive machine tools, chemical apparatus, library resources, scientific instruments, and electrical equipment in the Menlo Park laboratory complex (Hughes 1979, p.129).

It was not just people and materials that were inserted into the seamless web but also the traditional categories of social science demarcation. Following the systems builders themselves (following the actors), Hughes finds that they "were no respecters of knowledge categories or professional boundaries…Edison so thoroughly mixed matters commonly labelled 'economic', 'technical' and 'scientific' that his thoughts composed a

[19] Samuel Insull was a "manager-entrepreneur" who developed the Chicago Edison Company's system of electric light in the later period of the electrification of America; Mitchell was the "financial-entrepreneur" of the later period who introduced financial and organizational means by which the growth of utility systems might continue from regional levels to one national level (Hughes 1979).

seamless web" (Hughes 1988, p.13). "Edison's method of invention and development in the case of the electric light system was a blend of economics, technology and science…In his notebooks pages of economic calculations are mixed with pages reporting experimental data, and among these one encounters reasoned explications and hypothesis formulation based on science – the web is seamless" (Hughes 1979, p.135).

If one follows the actors, according to Hughes, one invariably finds it difficult to differentiate elements along the established lines of categorical interpretation. Instead, diverse elements (economics, politics, science, journalism, technology, etc.) join together into a system where one element is indistinguishable from the rest of the other elements. Thus, Hughes implies that the technological system of electrification was a sociotechnical system in which the social cannot be seen as lying behind and directing the technology. Neither can the technology be seen as lying behind and directing the social; rather, the sociotechnical influences the sociotechnical (Law 1987c, p.418).

The similarities between Hughes' approach and ANT are quite obvious: an emphasis on the sociotechnical as opposed to solely the social, technical, political or economic factors of technical development, and empirically focused studies of the systems builders themselves in order to generate the sociotechnical conclusion. The significant difference between the two approaches is the emphasis that ANT places upon conflict within the network. As the above example of the VEL shows, large scale heterogeneous engineering is difficult. Elements in the network continually prove difficult to tame, and thus vigilance and surveillance (via actors of varying durability) has to be maintained. It is the belief of the actor-network approach that actors will almost always fall out of line and that there is always some degree of divergence between what the elements of a network would do if left on their own and what they are obliged, encouraged or forced to do when they are enrolled in a network (Law 1987a, p.114).

This insight leads to two important aspects of ANT unaccounted for in Hughes' approach. First, ANT proposes that the relationship between the actors and the network is reciprocal. An actor-network is simultaneously an actor who whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of. Instead of viewing the network as linking in a predictable fashion all those elements that are perfectly defined and stable, ANT proposes that the entities of which an actor-network is composed could at anytime introduce new elements that change the network (Callon 1987, p.93). Under the terminology of ANT then, network does not mean transport without deformation; instead it reflects a series of mutual transformations (Latour 1999, p.15).

Secondly, and more importantly, is the notion of 'generalized symmetry' proposed by ANT. Symmetry, as was stated earlier (see footnote 10), was a concept developed within SSK to account equally for the existence of scientific beliefs, both false and true. This concept is taken a step further by ANT. If all entities are actor-networks involved in sociotechnical arrangements, and within these actor-networks and sociotechnical arrangements there is no difference, in kind, between the human and non-human elements, then it makes sense to adopt a vocabulary that treats the social, natural and technical with the same vocabulary, to not "change registers when we move from the technical to the social aspects of the problem studied" (Callon 1986b, p.200).

This move by ANT has been the subject of much debate[20] and therefore I find it necessary to qualify this position with a simple argument that explains the position of

[20] See the debate between Collins & Yearly (1992) & Callon & Latour (1992).

generalized symmetry. When one speaks of the 'social order', what is one speaking about? It cannot simply be the social, for without materials and associations of non-humans and humans the human social order would resemble the social order of baboons and there would be no explanation for the solid, durable macro-structures that we see forming everywhere in human society (Callon & Latour 1981, p.283).

> The somatic – the resources of the body – though these are already heterogeneous, are altogether inadequate to generate the kinds of social effects that we witness round about us. For orderings spread, or (sometimes) seek to spread, across time and space. But, and this is the problem, left to their own devices *human actions and words do not spread very far at all.* The conclusion is inescapable. Other materials, such as texts and technologies, surely form a crucial part of any ordering. (Law 1994, p.24)

This problem of accounting for nonhuman actors is inherent within sociology and social analysis. Latour (1992) declares that sociologists are always looking for social links that are sturdy enough to tie us all together or for moral laws that would be inflexible enough to make us behave properly. Unfortunately, the society that is being recomposed with bodies and norms is constantly crumbling. The remedy to this is ultimately equality between the human and nonhuman during the process of social investigation (Latour 1992, p.236). Generalized symmetry is not anti-human, it is the ultimate extension of methodological equality within sociotechnical networks. If ANT is prepared to apply this principle of equality, then it must be prepared to apply it without fear or favour (Lee & Brown 1994, p.776).

3.3 Translation

ANT, departing from social constructivism and systems theory through the use of generalized symmetry, generalized agnosticism, and relational materiality, presents a new form of analysis to the study of power in sociotechnical orders and specifically the role played by technology in structuring power relationships: the study of translation (Callon 1986b, p.197). Translation, at its core, is the study of power in the sociotechnical world described by the actor-network perspective.

In this sense, power is not a cause of action. Power is always an effect of associations between heterogeneous elements. Latour (1986) breaks with sociological tradition and contends that within this definition of power, society should not be seen as a structure that holds everything together. Rather, society it is what is held together through associations of humans and materials and the effect of these associations is that some manage to maintain power and some do not (p.276). Latour uses the example of an office manager to show how power is an effect of the resources surrounding this person. In this case, power is an effect generated by walls, record keeping, clothes and machines. Power does not reside in the position the manager holds, it resides in the materials that create his position (p.276).

Another example will help clarify this notion of power. The example of Robert Moses and his racist bridge designs found in Chapter One provides an example of how power, and the reversal of this power, is an effect of associations and not a cause. The inability of poor inner-city citizens to access Jones Beach was not caused by Moses' racism. It was the effect of Moses' racism, cement bridges, expensive automobiles, and 10 foot high public buses. The association of these elements led to the effect that poor urban citizens were not able to access Jones beach. Similarly, the shift in power, the ability to access the beach by those who were initially barred, was also an effect. The desire to overcome the racist structures that Moses built did not cause their demise. Rather, the effect of relatively inexpensive means to own an automobile in combination with roads already in existence resulted in the effect that the power relationship that existed previously was changed.

Problematization

The first step (or strategy) of translation is problematization, or how to become indispensable by making oneself an 'obligatory passage point' – a point which all entities must go through if they are to achieve their goal. To do this, a sociotechnical scenario must be created that determines a set of actors and defines their identities in such a way as to establish themselves as an obligatory passage point in the network of relationships that they are building. Problematization touches on a number of elements - social, natural and technical - and describes a system of alliances or associations between entities defining what they want (Callon 1986b, p.203-206). This is the first part of translation, creating a situation in which actors are dependent on you to get what they want.

In the case of the VEL, the EDF proposed a sociotechnical scenario in which they would become the obligatory passage point for a number of different actors with the explicit goal of enrolling these actors in their proposed network. The EDF says to its users (government and consumers): If you want to solve your pollution problem we must create an electric vehicle. If we want to build an electric vehicle we must first solve the problem of the short life of the electrochemical power sources needed for this vehicle. If the electric vehicle is to be successful you must agree with the social and technical definition that we propose (Callon 1986a, p.26-27). Problematization is thus a strategy of translation. This strategy creates a situation where potential users of the VEL consider their future and their values as passing through the EDF via problematization. As was stated above, the EDF not only determined the precise characteristics of the VEL, but also the social universe in which the vehicle would function. The EDF defined the roles of the actors and proposed a scenario in which these actors would define each other.

By identifying French society as urban, post-industrial and coming to terms with the changing landscape of transportation (influenced by new social movements aiming to improve the country by putting science and technology at the service of the user), the EDF defined a social and technological history for the VEL to develop in. They also defined the CGE (Compaignie Generale d'Electricite) as the company that would develop electric motors and batteries. Renault will produce the bodies of the VEL. The government will be responsible for formulating regulations favourable to the VEL including subsidies for municipalities interested in electric transportation. Lead accumulators, zinc/air accumulators, and fuel cells – in that successive order - are also defined as the key technical elements. In sum, the EDF has created a network in which numerous actors are defined by simply proposing a solution to pollution and traffic congestion that also matched the changing attitudes amongst French society towards status driven consumption and ecological responsibility. The EDF puts forward a list of entities and a list of what they do, think, want and experience.

This is not all that is accomplished through problematization. The relative size of actors is also determined. In the network proposed by EDF, Renault is no longer a major European manufacturer of cars and it will never regain that status. The relative status of lobby groups who act on behalf of the automobile and oil business are also reduced. Social movements who demand that technology serve the needs of the user instead of out-dated profit interests grow to gain much more influence (Callon 1986a, p.20-23).

Problematization makes it possible to describe both the contents of technical objects and theoretical knowledge without bias. A concise investigation of this technological innovation requires that the electrons, consumers, government ministries, Renault and social movements must all be accounted for. None of the entities can be placed in a hierarchy, or be distinguished according to its nature, as the absence of one entity would lead to a breakdown of the whole. The proposed VEL sociotechnical scenario is the result of heterogeneous engineering (Law 1986a), and cannot be understood unless considering all the elements that equally contribute to its development (Callon 1986a, p.23).

Enrolment

The network proposed by EDF is simply that, a proposal. The actual construction of the VEL needs much more than defined identities and roles of the actors. The EDF needs to construct this network by enrolling the actors in their defined roles so that they cannot be defined in other networks and they cannot envision their identity other than that of the definition proposed by EDF. Enrolment is essential for both the development of the VEL and for the EDF to become an obligatory passage point for all the actors identified during problematization. In this sense enrolment is the series of negotiations, trials of strength and tricks used to ensure the successful translation of the entities in the EDF's network (Callon 1986b, p.211). This is the point at which the EDF failed to realize their proposed network and instead Renault redefined their own successful network.

The enrolment of some actors does not need to be negotiated. Some actors willingly accept their enrolment without resistance. This would be the case for environmentally conscious consumers and potential users of the VEL. Some actors need other, more durable, means to ensure their successful enrolment. Renault, for a brief time, was forced into the EDF's network through scientific knowledge and social analysis. The facts that were presented by EDF were indisputable. In a post-1968 France, the social universe that EDF proposed and the VEL represented seemed inevitable. For three years nobody interrupted the progress of the EDF. Renault did not possess knowledge that even considered the dynamics of electrochemistry so they were forced to abide by their defined role in the EDF's network. Faced with the prospect of becoming a smaller and less powerful company, Renault attempted to enrol scientific knowledge via research laboratories and social analysis via statistics that countered the claims of EDF's engineers. Using the terminology of ANT and translation, Renault resisted enrolment and countered by attempting to define and enrol entities in their own network.

Renault was able to use statistics to show that despite an increase in gas prices, demand for the conventional automobile increased. These facts proved to be dissociable in practise and Renault translated social desires differently than EDF. People will always want private automobiles that take into consideration the speed, comfort and acceleration that the VEL will never have (Callon & Latour 1981, p.290). This translation of social desires and the evolution of the social world proved to be more durable in practise than the future the EDF proposed. Instead of seeing a social demand for a completely new system of transportation, Renault translated the data that it had collected and came up with different results. French consumers will not adhere to their new role as mature, ecologically responsible members of a post-industrial society. Instead they are content to seek social distinction, comfort and speed via the conventional car (Law & Mol 1995, p.284).

Successfully dissociating the social translations, Renault focused on the technical knowledge being used by EDF. Research laboratories were hired and the knowledge produced within these institutes showed that the calculations and experiments by EDF to develop the VEL were wrong. The proposed trajectory of the evolution of the electric engine (lead accumulators, zinc/air accumulators, fuel cells) was wrong. Unfortunately for EDF (or fortunately for Renault) the specific elements of the actual engine in progress did not need to be scrutinized by other networks. They proved to be difficult and eventually impossible to enrol because the catalysts refused to play their part in the scenario developed by the EDF, also rendering the trajectory of fuel cell development unusable (Callon 1987, p.91).

The EDF failed to make itself an obligatory passage point because it could not enrol all of the actors defined in their proposed network. Renault, on the other hand, was able to enrol the actors and therefore translate them into a whole, making itself an obligatory passage point for a significant portion of the transportation system in France and Europe.

As shown in this example, the process of translating actors is difficult and precarious. Using the concepts and language used by ANT suggests an interesting method for the study of technology and society by creating a way to understand how it is that macro-structures are able to exist amidst the complex number of actors enrolled and the strategies of translation used to ensure that these networks are durable. Examining the heterogeneous associations necessary for stable macro-structures to exist allows a new insight into the relationship between society, technology and power.

3.4 ANT: Translation, Technology & Society

It is now possible to fully examine technology within the actor-network perspective. This will entail, first, a clear definition of the role of technology in society, and second, a vocabulary to account for technology's role in society.

Society is made up of sociotechnical relations and associations. In this sociotechnical world, humans build lasting macro social structures by appealing to and enrolling entities that are more durable than the intentions that initially led to their construction. The idea that France should adopt electric vehicles in order to appeal to the social demands of post-industrial consumers and help to eliminate both noise and environmental pollution does not work in practise without the nonhuman entities enrolled in the construction of the electric engine. We are never faced with networks that are associations of humans or nonhumans exclusively. If this was the case you would have purely social relations demanding a change in the culture of the automobile and nothing else or an electric vehicle that has no place in France because humans have not been accounted for in the demand, production, or use of the VEL (Latour 1991, p.110).

We now have a very different conception of the role of technology in society. No longer is technology a determining influence or a neutral tool that reflects the needs of the user. Technology is, as Latour makes clear in the title of an article, "society made durable" (Latour 1991). This new approach to what the social is necessitates a new vocabulary for the role of technology. If technology's role is as stated above, it may no longer be useful to account for it by referring to existing descriptions predicated on a separation of technology and society. We know how to describe human relations, we know how to describe technology, we know how to talk about the influence of technology on society and vice versa, but there is a lack of vocabulary for thinking about these aspects as an integrated whole. This is unfortunate, because whenever a stable social structure is found, it is inevitable that technologies of some kind are essential to its relative durability (Latour 1988a, p.299; Latour 1991, p.111).

Technology translates a vision of the world in the technical content of the new object. The end product of this translation is a 'script' or sociotechnical 'scenario' (Akrich 1992, p.208). This translation is dependent on 'pre-inscription', all the translations that need to be done by an actor before a scenario is played out, all the things assimilated by an actor before being translated by the scenario (Latour 1988a, p.307). These actions are not predictable though, and the translations that are relied upon may at any time dissipate. The EDF developed a scenario in which their innovation, the VEL, was to play the central role. In order for this to happen they needed to translate a vision of the world that would be realized in the working VEL. Necessary for this is what the scenario presupposes from its enrolled actors: the pre-inscription. It is assumed, and necessary, that actors in the EDF network are pre-inscribed already with competencies needed for the success of the VEL. Consumers must be pre-inscribed as upset with the direction of the automobile; government must be pre-inscribed as supportive of the VEL, and the research laboratories must be pre-inscribed as having the knowledge to successfully enrol the technical elements in the VEL's engine.

If these steps are performed and the technical object is realized, it in turn translates behaviour back onto the human user. Translation then is the moral and ethical dimension of technology (Latour 1992, p.232). The VEL, if it was successful, would prescribe in the user a specific morality relevant to the use of the automobile. The VEL would prescribe to the user that he/she is mindful of environmental concerns, that he/she is not concerned with travelling at excessive speeds, and that the user is not concerned with relating the ownership and use of an automobile with social status. The VEL prescribes, or translates, specific features of the user so that he/she does not know that they want anything else. This is possible because these translations are made durable by the successful working of both social and technical elements embodied in the VEL.

Nothing in a given scenario can prevent the inscribed actors from behaving differently from what was expected (Latour 1992, p.237). This is clear in the example of the VEL. Social groups can change their mind and demand better public transportation instead of an electric vehicle; zinc/air accumulators can become contaminated and not fulfill their inscribed role; Renault can do everything in their power to avoid being reduced to a smaller and less powerful corporation. It is these conflicts that create a situation in which it is necessary to follow all of the actors in order to understand how a specific technology can come to be stabilized and performed. To follow the actors during the processes that lead up to the final, stable technology, is to follow the negotiations between the innovators and the users and to study the way in which the results of these negotiations are translated into technological form (Akrich 1992, p.208).

Technology can therefore be seen as an object that embodies two dimensions, the social and the technical. Technology in its final form can thus be examined from both dimensions. First, by examining it from the perspective of who it is designed to enrol, and second, what it is tied to so as to make the enrolment inescapable. Latour (1987) describes this process as viewing both the 'sociogram' and 'technogram' of any artefact, any information you have for one system is also information on the other (p.138). If the VEL worked and was used you could therefore see in the technology (the VEL) how it translates the social (urban, post-industrial & environmentally concerned) and in the social how it translates the technology (ecologically responsible, egalitarian transportation). At no time does one aspect determine the other.

Chapter Four – Sociotechnical Power: The Technical Code & Translation

The previous two chapters examined how both the CTT and ANT conceive of power in modern technological society. Addressing the critiques that Feenberg has of ANT and showing the potential of ANT to complement the CTT will be the focus of this chapter. Arriving at that point will require, first, a review of the underlying concept of the 'sociotechnical' that guides both the CTT and ANT. Following this, I will re-interpret both the technical code and translation from a sociotechnical perspective as two complementary insights that address the same basic concern from different perspectives. These insights will provide a basis to re-examine and address Feenberg's critiques of ANT.

4.1 The Sociotechnical

Studies of technology and society often regard technology as either neutral or deterministic. Technological neutrality is based on the idea that technologies are tools that stand under the same norm of efficiency in each and every social context. Technology is not pre-disposed to achieve specific ends as it contains a universal rationality that renders technology neither socially nor politically relative (Feenberg 2002, p.6). Technological determinism is best defined as the belief that technical change is the prime mover of social change. This perspective on technology is reflected in terminology like 'the information society', 'the industrial age' or, 'the computer age'. What these terms have in common is the belief that technology stands behind and is the determining factor in defining society.

Although different in their interpretation of technology, both technological neutrality and technological determinism share two commonalities in their understanding of technology. First, technology is destiny. Both theories share a 'take it or leave it' attitude toward technology and regard technological rationality as beyond the scope of human intervention. The idea that technology is inherently disposed to reflect social values and could, in a different society, be radically changed lies outside the parameters that bound technological determinism and neutrality (Feenberg 2002, p.8). Second, both separate technology and society as two different categories of study. This ontological separation exists only in abstraction and does not reflect the actual process of living in a technological society. Anyone who lives in modern technological society knows that what is defined as social is usually mediated to some degree by technology, and what is defined as technology does not exist without human users.

The alternative to both technological neutrality and determinism can be found in the concept of the 'sociotechnical'. This concept is primarily based on two features discovered through empirical analysis of technological innovation, design and stabilization[21]. First, neither society nor technologies exist in isolation from each other. Society is bound together by technology as much as technology is bound together by society. It is only in the wilder reaches of science fiction, or quite possibly on nude beaches, that one can observe either a pure technological or social order (Law & Bijker 1992b, p.290). Second, if the 'social' order is held together by technological means, it cannot be assumed that this order is durable and stable. What is called the social order may at any time change or fail as technologies change or fail. Neither technology nor social institutions move along linear paths of trajectory: their paths are variable and contingent on a number of non-social or non-technical elements (Law & Bijker 1992b, p.291).

[21] For a collection of studies that employ the concept of the sociotechnical see Bijker & Law (1992).

By embodying a concept of the sociotechnical in their theories, both ANT and the CTT share a similar strategic point of departure. It is quite easy to identify the influence of the sociotechnical perspective in ANT. The primary focus and analytical emphasis on the heterogeneity of the social makes it clear that the two features of the sociotechnical mentioned above - the social is not purely social and sociotechnical orders can change - are given in any ANT-influenced study. Feenberg's CTT on the other hand is not as explicit as ANT in its reliance on the concept of the sociotechnical. Although there are a number of emblematic quotes in *Transforming Technology* that could be used to show Feenberg's use of the sociotechnical, the best evidence can be found in the concept of the technical code. It is clear that Feenberg does not regard technology as being determined by solely technological factors. The social requirements of capitalism are as much a part of technology as the technical elements. Second, by identifying the social influence on technology, Feenberg also identifies technology's influence on society. This can be found in his examination of how capitalist technology determines specific social functions such as a capitalist division of labour. In this way, the CTT complies with the first aspect of the sociotechnical perspective: technologies are never completely technological, and society is never purely social. The second aspect of the sociotechnical perspective is made much more forcefully in the CTT: technologies are predisposed to meet different social requirements, resulting in a theory of technology that recognizes the inherent potentiality of technology to exist in a variety of forms different than the forms that surround us today.

Employing the concept of the sociotechnical allows one to re-examine the CTT and ANT from a perspective that differs from Feenberg's critique of ANT. It is my contention that both theories, and more specifically their conceptions of power, provide a complementary understanding of the sociotechnical. If, as is implied by adopting a sociotechnical perspective, sociotechnical orders can exist in many different forms, why do we exist in a relatively stable sociotechnical order, and how is this complexity stabilized and black boxed?

The first part of this question, why the sociotechnical is the way that it is, is answered by the CTT. Our contemporary sociotechnical order takes the form that it does because of the influence of capital. The capitalist technical code determines the social function of technology which reproduces and extends the power of capital at the expense of environmental and humanistic concerns. Technology can change, though, and Feenberg develops the concept of technological ambivalence to identify the point at which technology is relatively neutral concerning the role that social influences play in its development. Without reverting to fatalism, sociotechnical regression, or the call for the destruction of all technology, Feenberg is able to identify the negative effects of contemporary technology, but also provides a theory of technological change that recognizes the existing technological base for progressive change.

The CTT does not completely answer the second part of the question, how do capitalist sociotechnical arrangements remain durable and spread over time and space? Although Feenberg makes it clear that the process of technological innovation, and by result technology itself, is oriented towards a given reality and not potentialities, he is unable convincingly to provide an analytical model that can identify the technical code as it is applied in different technologies. Using the insights of ANT, one can use a vocabulary and analytical strategy to 'open the black box' of technology and potentially discover the point at which the technical code of capitalism is applied. This differs from the CTT in the sense that an ANT analysis would be premised on the understanding that the technical code is applied at different phases of innovation depending on the technology in question. Thus, the ambivalence of technology can also be discovered at different points of technological innovation.

Theorizing about the potential for technological change and applying these insights in practise is where ANT can complement the CTT. There currently exist a number of technologies that can already reflect positive social influences. Information and communication technologies and technologies that provide the infrastructure for modern communities are fields that contain examples of technologies that can contribute a clear social good. There are also technologies that solely benefit the demands of capitalism at the expense of humans and the environment: hidden consumer and public surveillance technology[22], technologies that create unequal access to information (digital copyright management systems)[23], and of course, nuclear weapons. These examples are used to show that in some cases there is an evident dichotomy between the positive and negative social influences and implications of technology, but in most cases the claim that a technology is influenced by positive social goals is difficult to make. Is the technical code applied to personal computing technology? At what point in its development is it applied? This question could be asked of a number of technologies that, like the personal computer, cannot be uniquely defined as 'ambivalent' or a source of capitalist power.

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[22] See Samarajiva (1996).
[23] See Cohen (1996).

Discovering how these technologies are embedded with the technical code is the complementary aspect of ANT that can assist in developing a critical theory of technology that can be applied in practise. Because the CTT does not provide either an analytical strategy or a vocabulary that can fully account for power in the sociotechnical world, and because ANT does not articulate a need or strategy for sociotechnical change, both theories can complement each other by providing a reason why sociotechnical change is needed, and the means to achieve this change.

By adopting an ANT perspective in answer to the question of how sociotechnical orders maintain their durability over time, the CTT can be influenced by an analytical model that better reflects sociotechnical complexity. The theorists by whom Feenberg is influenced, Marx and Marcuse, lack a concept of the sociotechnical, generating problems that Feenberg remedies by using a sociotechnical model of analysis. ANT is based on the premise of the sociotechnical and does not need to identify this feature in its formulations as being significant from other theories of technology. Rather, ANT is focused on devising an analytical strategy and terminology to account for how power is achieved and maintained in a sociotechnical order. Translation is the core concept it employs to this end. ANT provides a single and unified vocabulary that describes the work of creating and imposing the social and the technical (Law 1986b, p.4). By using ANT in this way, the CTT can acquire a tool to identify the ambivalence of technology and to map more completely the technical code.

4.2 Translation & The Technical Code

The technical code provides a concept that examines why the sociotechnical takes the form that it does. Any technological artefact embodies both technical elements and social requirements. Identical to the ANT idea that the social can be seen in the technical and the technical in the social, the technical code can be understood as a form of translation. The technical code translates humans that are enrolled in sociotechnical orders via technology and translates social aspects in technology by embodying a specific form of technological rationality. These aspects can be seen in Feenberg's example of the technical code of capitalism as it is applied to the assembly line.

> The assembly line is an excellent example of a technology influenced by [the technical code]: a strategy of technologically enforced labour discipline forms the glue that holds together the elements from which it is composed. This asymmetrical effect on power is characteristic of a strategically encoded technology (Feenberg 2002, p.78)

Technology can also be strategically encoded by a different technical code by translating social interests and technology in a completely different configuration:

> The assembly line only appears as technical progress because it extends the kind of administrative rationality on which capitalism already depends. It might not be perceived as an advance in the context of an economy based on workers' cooperatives in which labour discipline was self-imposed rather than imposed from above. (Feenberg 2002, p.78-9)

Technologies are tools of translation. They durably translate actors. The contemporary assembly line translates workers as non-owners that "are indifferent to the welfare of the firm" (Feenberg 2002, p.78). The VEL translates drivers as environmentally responsible, unconcerned with speed and progressively post-industrial. Feenberg recognizes this aspect of translation in the technical code. The technical code coordinates social determinants in technologies that are evident by examining the social and environmental effects of technological mediation. Technology, in this sense, only refers to the end product, the punctualized actor. However, any actor is the effect of interaction between heterogeneous elements, and thus "punctualization converts an entire network into a single point or node in another network" (Callon 1991, p.153).

Following the actors allows an examination of the way in which these actors attempt to impose their sociotechnical worldview on other actors, and more importantly, how these actors resist or accept the translations proposed. As was detailed in the example of the VEL, every actor in the proposed sociotechnical network had to be translated for the network to be successful. How would these translations be achieved? By using scientific knowledge and data derived from social analysis. By encouraging the government to subsidize communities who want electric-powered public transportation. By creating a sociotechnical world in which the traditional automobile was doomed as a relic of a previous age. The translations were to be achieved using a variety of materials to enrol actors in the network. Identifying the processes and materials used to create sociotechnical orders can in turn discover the point at which the technical code is applied. The technical code is not an 'invisible hand' or a 'phantom' that guides technological innovation. It can be found in textbooks, managerial decisions, sociotechnical scenarios and interpretation of data. All of the translations that were combined in the construction of the VEL were necessary and they had to exist as real interactions between actors. Examining the assembly line in this way would reveal the processes, negotiations and materials that were used to create an obvious example of how the capitalist technical code is applied. Applying these insights to a punctualized technological artefact is no different.

If a technology exerts power over people and the environment, this is an effect of the heterogeneous elements that make it up. Appealing to a single source of power to explain domination is mistaken; identifying the interactions that create this effect provides a more concise and realistic explanation (Latour 1986). It is not enough to say that 'capital' determines the form and function of technology. What is needed is the exact identification of how capitalism exists in the interactions that create the technical code of capitalism. If the technical code is the expression of power in sociotechnical orders, then discovering how this power expands and reproduces itself means studying the interactions that create the effects of the technical code. Tracing its influence requires examining the translations that enrol actors who would, on their own, not choose to be enrolled.

If, as Feenberg states, technology is politics and social control pursued by other means then the only way to advance a democratic politics of technology in an intensely technically mediated society is to get inside the technology, to penetrate to the point where technology and society mutually and simultaneously define one another (Latour 1988c, p.39). This is the point, in Feenberg's terms, at which capitalists are able to exercise operational autonomy, the point at which the technical code is applied, the point at which technology is ambivalent towards different social systems, and therefore, this is where analysis should focus. The democratization of a technology-intensive society is antithetical to a world in which those who control technological development are the few instead of the many.

Following the actors as they move, define, manipulate and enrol other actors does not limit itself solely to humans. Technologies are actors that translate other actors. They are also networks that are built up from heterogeneous elements. Identifying how these elements are translated reveals in detail the point at which the technical code of capitalism is applied to technology. Sociotechnical change is premised on the notion that the technologies that we are currently gifted with may all be encoded with the technical code of capitalism, but this encoding does not exist as a process that is identical in each and every case. Rather, the ambivalent nature of technology can be discovered at different points within different technologies. This insight can only complement Feenberg's theory as it also recognizes the technological base already in existence that can be used to reflect a socialist technical code.

4.3 Addressing Feenberg's Critiques

Feenberg's critique of ANT from a CTT perspective can be reinterpreted as a critique of three aspects of the ANT strategy: the strategy of following the actors, generalized symmetry, and generalized agnosticism. These aspects should not be understood as standing against the insights of the CTT. Rather, these insights should be understood as tools that can provide an answer to the second aspect of sociotechnical power – how sociotechnical arrangements are able to maintain their durability and expand over time and space.

The first of these critiques, following the actors, can be found in Feenberg's assertion that ANT contains "disturbing normative implications" because it studies technology from the 'winners' point of view. This can be understood as a critique of 'following the actors' during the process of developing technology. Remedying this critique involves re-examining 'following the actors' from two similar perspectives influenced by goals of the CTT. First, the ANT canon contains a number of studies that focus on technologies that were unsuccessful, including the VEL detailed in Chapter three. Not focusing on solely successful technologies, ANT can provide the CTT with a perspective on technological innovation that identifies the reason for unsuccessful innovation. If, for instance, a proposal for a manufacturing assembly line is introduced that reflects the requirements of a different society and focuses on re-skilling, instead of de-skilling, the workers, this design would be rejected by the capitalists who control the production facility. Using an ANT analysis can serve as an important tool for the CTT because it would clearly identify the strategies of those who oppose this specific technological innovation and help reveal the technical code of capitalism as a determining force in technological innovation. In turn, this could expose the inherent social contingency of technology, negating any assumption of technological neutrality.

By examining those networks and actors that are successful, those that are powerful, it is possible to show that they are no different, in kind, from the rest of us. They are not better or marked as different, just bigger. Thus, ANT provides a tool for debunking the myth of the 'great person' who is treated as different from all others. ANT contends that it is an analytical mistake to think of the large and powerful in any different way then you would anyone or anything else (Law 1991b, p.12). In this way, ANT provides a perspective that further reveals the sociotechnical and the CTT concept of the inherent potential for technological change. Showing that technologies are solely the result of networked entities and could exist differently in a different social context allows for an approach that quickly refutes the concepts of those who insist on a determinist or neutral approach to technology. Showing that the technology that we are endowed could indeed be different systematically rejects the linear model of technological innovation and the rationality that stands behind it.

Second, the reason for looking at those who succeed is precisely because they have succeeded,

> They are bigger and more powerful, everything else being equal, their modes of organising and ordering shape much more about the heterogeneous networks of the social than do the strategies of the unsuccessful. So if we want to understand the modern world, it does not do to look at failures. (Law 1991b, p.13).

Does this mean that, as was stated in Chapter 1, "from Law's account of Portuguese colonial expansion we learn a lot about the (ultimately) successful actors, but hardly anything about the perspectives of the colonized inhabitants of Africa or India" (Radder 1992, p.162) ? Yes and No. Yes, Radder is correct: most ANT studies do not recognize the demands of those who are oppressed in networks. But, this approach does not seek to represent the perspective of the victims of Portuguese imperialism or any other successful network; it only seeks to understand how, and through what materials, this action is achieved. A simple rejection of Radder's critique would be that regardless of the concern for the victims of Portuguese imperialism, this event occurred. Instead of seeking to examine what should or could have occurred, ANT seeks only to examine how this occurred and through what means this was achieved[24]. However, providing an examination of the tools and materials used by the Portuguese can provide an understanding of how they were successful and how their technology was encoded to provide specific results.

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[24] The basis of this particular case study, the Portuguese expansion into India, is explained by Law when he writes, "Columbus's discovery of the New World in 1492, when taken with the arrival of heavily armed Portuguese vessels in the Indian Ocean in 1498, clearly marks an important turning point in the balance of power between Europe and the rest of the world. From that moment onwards until the very recent past the rest of the world has been under European control and domination" (Law 1986a, p.234). The question he asks is, "How was it that Christian Europe, at the turn of the 15th century, hemmed in in the East by predatory Muslim powers, succeeded so dramatically in turning the tables?" (Law 1986, p.236)

The strategy of social domination and the need to overcome this domination is evident in Feenberg's account of technology. Tracing how this domination is maintained can be accomplished by tracing the translations that it is dependent on. Simply recognizing the demands of those who are enrolled in networks does little to examine the exact processes by which this is achieved. Discovering these translations can lead to resistance by identifying the materials and processes that those who control others are dependent upon. The critical theory of technology provides a voice for those who are oppressed in sociotechnical orders, and articulating this voice means also recognizing how it became oppressed. In order for sociotechnical change to recognize the ambivalence of technology and proceed with a socialist technical code it is necessary to examine at which point in the process of design the technical code is applied. As was stated earlier, this point may exist at different phases of the design process. Examining successful technological innovations can only reflect the insight that some technologies do indeed provide a clear social good while others do not. It is not desirable to simply critique the totality of human technological innovations; instead, we must employ a model of examination that can show why some technologies need not be significantly transformed and why some others should be.

The second aspect of Feenberg's critique is focused on the ANT concept of generalized symmetry. Feenberg argues that this particular aspect of ANT is logically incoherent. Generalized symmetry is a 'questionable' approach to technology because it endows nonhumans with agency when "it is after all 'we' who do the distributing" between what is human and nonhuman (Feenberg 2000, p.153). As was explained in Chapter 3, ANT does not disregard the influence or importance of humans, it is simply an analytical strategy. "The distinction between humans and machines is subordinated to another concern – that of exploring the development of a complex sociotechnical system" (Law 1991b, p.10). ANT does not assume that there exists no difference between humans and nonhumans. Rather, it charts a course for investigating the sociotechnical that assumes that both humans and nonhumans play a significant role in the sociotechnical dynamic by recognizing that what is generally called human contains technical elements that help define the humanness of any social agent (Callon & Law 1997, p.168).

Viewing ANT as a means of understanding how power is maintained legitimates generalized symmetry as a viable approach to sociotechnical orders. Because Feenberg concerns himself with why these orders exist, he is unable to appreciate the potential insights of generalized symmetry to serve as a tool within the CTT. The value of this approach is detailed in the following example.

Re-examining Langdon Winner's examination of technologically enforced racism in New York, the attributes of ANT and generalized symmetry are made evident. Robert Moses, in the language of Feenberg, embedded a racist technical code in the bridges that he built. The dialectical concept of technological rationality in this case is clear: the design of the bridge has the potential to provide access to all public parks, but this reality is structurally blocked by Moses' racist social beliefs that are expressed through this specific technical code.

Feenberg critiques generalized symmetry because it is humans, and only humans, who can measure the potential of technology against the reality. "Reflexivity of this sort is essentially different from the contributions of nonhuman actors, and forms the basis for social struggles that may challenge or disrupt the networks and even reconfigure them in new forms" (Feenberg 2002, p.34). Back in New York, what people thought of these bridges mattered little as they could not rebuild them to better accommodate themselves and the others who were affected by them. Social groups were able to resist this racist oppression, not by building new bridges, but by being newly empowered through roads and the cars that undid the translations that the bridge and its social effects were predicated on. The power of this technology was transformed by material, and not social, means (Law 1991a, p.176).

This example highlights both the complexity of technology and the possible forms of resistance that can be identified. Unable to challenge the bridges by direct means, the technical code was overcome by reversing the translations that made it a powerful network. In this specific case, resistance was achieved by appealing to a simplified actor in the complex network embodied by the bridge. Once that actor was changed, the network was also changed. This marks an interesting insight that ANT can lend to the CTT. The ambivalence of technology can potentially be found in the simplified actors that make up a sociotechnical network. Tracing the translations that lead to stable sociotechnical orders provides a means to identify multiple forms of resistance by identifying, and attempting to reverse, the translations that sociotechnical networks are built up from.

Generalized symmetry is also a primary aspect of the socialist technical code developed by Feenberg.

> A socialist technical code would be oriented towards the reintegration of the contexts and secondary qualities of both the subjects and objects of capitalist technique. These include ecological, medical, aesthetic, urbanistic, and work-democratic considerations that capitalist

> and communist societies encounter as "problems," "externalities," and "crisis." (Feenberg 2002, p.184).

It appears that a socialist technical code would reintegrate all of these aspects into a new form of technological rationality. This form of socialist technological rationality would thus take into consideration a number of actors that are ignored under the capitalist technical code. Environmental aspects and aesthetic concerns would not be placed outside of technological concern, they would be as important as the technical elements that make up the technology and the users/subjects of technology. In this way, adopting a principle of generalized symmetry allows for a form of technological rationality that unquestioningly accounts for all human and nonhuman actors of sociotechnical development. Generalized symmetry represents an ontological transformation necessary to overcome capitalist technological rationality and legitimate a socialist technical code.

The third critique that Feenberg has of ANT is focused on the concept of generalized agnosticism. Recognizing the transcendent goals of a different social system and technology is not something that ANT explicitly accounts for. I do not disagree, nor seek to remedy this critique, because it is premised on Feenberg's understanding of why sociotechnical arrangements take the form that they do. It is not within the analytical strategy of ANT to discover transcendent goals that could be applied to sociotechnical arrangements. ANT seeks only to answer how these arrangements are made durable. Understanding that this aspect of ANT is a limitation from the CTT perspective shows only the potential of the CTT to reciprocally complement ANT in a similar way to how ANT can potentially complement the CTT.

4.4 Revealing the Technical Code

Both the CTT and ANT can complement each other with their insights and analytical strategies. Although there is a significant difference in what both seek to identify, this is remedied by using elements of ANT to complement the insight of the CTT. Providing an answer to why sociotechnical arrangements take the form that they do reveals the negative social and environmental influence of capitalism. However, applying these insights requires an analytical strategy that can account for the complexity that stands behind sociotechnical arrangements. It is not enough, I contend, to simply state that capitalism as a social system contains within it a specific form of rationality embodied in its technical code that is detrimental to the interests of those who value humanist or environmental concerns. Although this insight is essential in any formulation for radical sociotechnical transformation, the CTT is in need of an analytical strategy that can enable it to influence change without mistakenly accounting for the implications of such radical change.

Revealing the technical code through the actual processes and materials used by those who control the direction of technological design cannot only identify the actual point at which each technology we use is encoded by capitalism, it can also be used to identify technologies that are not encoded by capitalism. I find it difficult to comprehend that the technical code of capitalism influences the design of manufacturing technology in the same way that it may encode the plumbing and sewer systems found in our society. Because of this, the goal of transforming technology needs to be aware of the complexities that stand behind and create the technologies that exist in our modern society.

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